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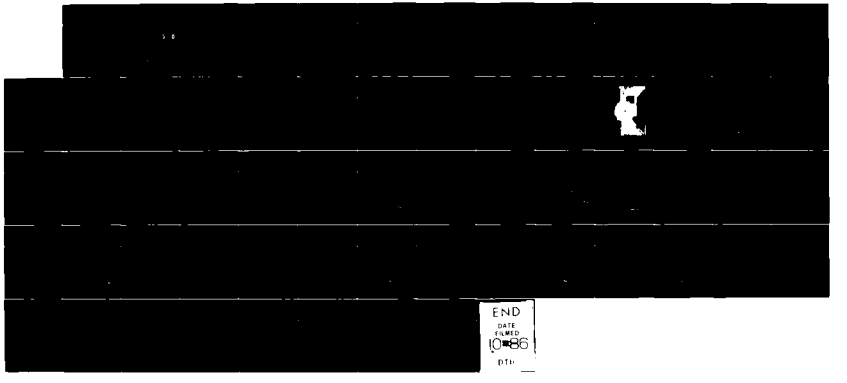

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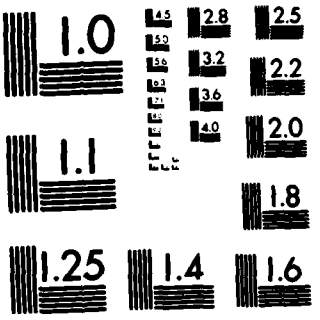

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Halon Extinguisher Agent Behavior in a Ventilated Small Aircraft

AD-A171 361

Gerald R. Slusher
Joseph Wright
James Demaree

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June 1986

Final Report

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16. Abstract

Hand held fire extinguishers (Halon 1211 and Halon 1301) were evaluated in a four-passenger Cessna Model 210C aircraft. The aircraft was operated in the FAA's Technical Center airflow facility under simulated flight conditions. Extinguishers were discharged without fires to determine the dissipation rate and toxicity levels of Halon extinguishing agents. Agent concentrations dissipated rapidly. Analysis of dose calculations demonstrated that 2.5 pound Halon 1211 and 3.0 pound Halon 1301 extinguishers were safe in the four-pasenger test aircraft. Dose calculations for the pilot were a maximum of 60 percent of the limit for Halon 1211, and maximum dose was 31 percent of the limit for Halon 1301. Stratification of the Halons together with cabin ventilation resulted in safe conditions for the pilot.

Distribution of extinguishing agents under the instrument panel was investigated. When the extinguishers were discharged on either the pilot's or the copilot's side, four percent concentration was measured on the side opposite of the discharge of the extinguishers. Extinguisher gas stratification was determined by measuring agent levels on the cabin floor.

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EXECUTIVE SUMMARY

Testing of Halon 1211 and Halon 1301 hand fire extinguishers was conducted in a Cessna Model 210C airplane mounted in an airflow facility. The facility was operated at an airspeed of 120 miles per hour for evaluation of extinguisher performance.

Extinguishers were discharged to determine the dissipation rate and toxicity levels of Halon extinguishing agents. These tests were conducted without fire, and involved the continuous sampling of neat Halon 1211 and Halon 1301 agents from three locations. Agent concentration was measured at the pilot's nose height, at pilot-copilot belt level, and at locations in proximity to discharge of the extinguisher. Discharge and associated testing were conducted remotely and observed and recorded by video systems.

Available general aviation fire related accidents statistics show that 87 percent of cabin fires are electric in origin. This problem is, for the most part, located under the instrument panel and was addressed by conducting eight extinguisher discharge tests in this area. A total of 28 tests was completed with the primary variables being agent discharge location and ventilation conditions. Extinguishers were discharged under the instrument panel, and at the fuel and hydraulic selector valves, copilot's seat, rear passenger's seat, and baggage compartment. Ventilation was varied by adjusting the overhead ports.

Ventilation airflow into the cabin was higher than previously thought possible. Time for a cabin air change at an airspeed of 120 miles per hour was 1.2 minutes, and at 140 miles per hour was 1 minute (reference 1.)

The significant result from this investigation was that 2.5-pound Halon 1211 and 3-pound Halon 1301 extinguishers were safe for use in aircraft comparable to Cessna Model 210C. Dose calculation for the pilot's nose height was only 60 percent of the recommended maximum for Halon 1211 and 31 percent of the limit dose for Halon 1301. Cabin ventilation airflow, together with agent stratification, produced safe conditions throughout the cabin study.

Distribution and stratification of extinguishing agents were investigated. When extinguishers were discharged under the instrument panel, pilot or copilot's side, 4 percent agent was measured on the opposite side. Extinguisher gases were measured on the cabin floor and the measured concentrations were in excess of 11 percent.

INTRODUCTION

PURPOSE.

The purpose of this report was to investigate Halon 1211 and Halon 1301 hand fire extinguishers for use in nonpressurized general aviation aircraft.

BACKGROUND.

This effort was undertaken to evaluate and compare hand fire extinguishers of Halon 1211 (reference 1) with Halon 1301 in a Cessna Model 210C aircraft. Further testing was designed to be more realistic by the utilization of four mannequins or test dummies for the passenger seating arrangement, and baggage was placed in the baggage compartment. Hand fire extinguishers for general aviation aircraft are not required by the Federal Aviation Administration (FAA). As noted in reference 1, aircraft owners are requesting installation of fire extinguishers by the manufacturers or are installing extinguishers of their selection. The Underwriters Laboratory specifies that a 2.5-pound Halon 1211 fire extinguisher should not be used in enclosure volumes less than 312 cubic feet. It was further demonstrated in reference 1 that only large twin engine aircraft have cabin volumes equal to or exceeding this limit. However, the test results of reference 1 showed that cabin ventilation was greater than previously thought and together with stratification of the Halon 1211 agents resulted in safe conditions at the pilot's nose. The molecular weight of air is 28.97, the molecular weight of Halon 1211 is 165.38, and that of Halon 1301 is 148.93. The molecular weight of Halon divided by the molecular weight of air shows Halon 1211 and Halon 1301 to be 5.7 and 5.1 times heavier than air, respectively. As defined by reference 2, the two Halon extinguisher agents evaluated are:

1. Halon 1211, Bromochlorodifluoromethane.

2. Halon 1301, Bromotrifluoromethane.

Extinguisher size selection should consider the volume and ventilation air change time of the compartment in which the extinguisher is to be used as advised in reference 3. Maximum recommended dose was also defined as extinguisher discharge that will not produce Halon 1211 concentrations greater than 4 percent for 1 minute, 2 percent for 2 minutes, or 1 percent for 4 minutes. For Halon 1301, maximum recommended dose was defined as exposure to concentrations up to 10 percent for 1 minute, 5 percent for 2 minutes, or 2.5 percent for 4 minutes.

DISCUSSION

DESCRIPTION OF FACILITY.

A 10-foot diameter by 24-foot-long airflow facility was designed and constructed from flat 4-foot by 8-foot sheets of low carbon steel. The cross section, figure 1, is octagonal in shape. The entrance is a bellmouth design with a 5-foot radius. This extension is attached to an existing 5-foot diameter airflow facility, figures 2 and 3. Performance of the 5-foot facility is near Mach 1 airspeed. Two J57 turbo jet engines provide power to drive the facility by ejector action. The 10-foot

diameter extension was designed for a minimum airspeed of 100 knots. Measurements with a Cessna 210C aircraft installed has indicated that airspeeds of 140 to 150 miles per hour (120 to 130 knots) are achievable. The increase over design performance is attributed to the propeller supercharging action, the increased local airspeeds resulting from decrease in tunnel cross-section area from the installed Cessna 210 aircraft, and improved contour development of the wind tunnel walls.

DESCRIPTION OF AIRCRAFT.

The test article is a 1963 model Cessna 210C with retractable landing gear (figures 2 and 3). The airplane is a four-place high-wing monoplane, powered by a single six-cylinder, horizontally-opposed fuel injection Continental I0470 engine. For installation in the facility, mounts were designed, fabricated, and installed at the wing spar attachment points and at the wing strut attachment points. The fuselage was installed in the tunnel with 3/4-inch high carbon steel rods connected to the mounts and to the tunnel walls. The wings were cut at the 32-inch section and then were installed on the fuselage in the tunnel. The sections were installed to provide the cabin ventilation air inlet ports located in the wings. It was necessary to move the ports inboard for inclusion in the 32-inch wing root sections.

MEASUREMENT OF EXTINGUISHING AGENTS.

An environmentally controlled trailer was utilized for measurement of fire extinguishing agents of primary interest. Halon 1211 or Halon 1301 was measured at three cabin locations with three Beckman model 865 gas analyzers. The analyzer detector, purchased from Beckman Instruments Company, was changed to detect the agent being tested. In addition, an optical filter was added to eliminate sensitivity to water vapor. Calibration gases of Halon 1211 and 1301 concentrations were used at 3.0, 6.0, and 8.0 percent. Calibrations were checked before and after each test. Ancillary components utilized were sample pumps, sample transport tubing, and sample flow controls. The signals were recorded by a computer. The measurements were plotted against time in seconds.

DOCUMENTED FIRE LOCATIONS.

Table 1 was excerpted from reference 1. The information is from the FAA Service Difficulty Reports. The table shows that 86.7 percent of cabin fires in general aviation aircraft are electric or electronic in origin.

TABLE 1. CABIN FIRE STATISTICS

(Involving Smoking Materials, Electrical Origin, Hand Held Extinguishers)

Year	Incidents No.	Smoking Materials No. (%)	Electrical Origin No. (%)	Hand-Held-Use No. (%)
1976	15	---	14 (93.3)	---
1977	10	1 (10.0)	9 (90.0)	---
1978	8	1 (12.5)	7 (87.5)	---
1979	23	3 (13.0)	21 (91.3)	---
1980	19	---	16 (78.9)	---
1981	8	---	7 (87.5)	---
TOTAL	83	5 (6.0)	72 (86.7)	NONE RECORDED

The electrical and electronic components are primarily located in and under the instrument panel. The instrument panel for the test aircraft (Cessna 210) is shown in figure 4. Identification of the equipment is also listed. Electrical power for the aircraft is supplied by a 12-volt direct current, negative ground electrical system. A single 12-volt battery supplies power for starting and provides reserve power in the event of a generator or alternator failure. On the extreme left side of the instrument panel, one item that could be involved in a fire is the master switch. Operation of the switch connects the battery solenoid coil and the generator field coil to ground, thereby, activating the power system.

The ignition start switch is utilized to check the magnetos and is also used to engage the starter solenoid. The auxiliary fuel pump switch operates two electric fuel pumps connected in series and located in the nose-gear well. Additional electric units located in the left-hand side of the instrument panel include a number of circuit breakers, a pitot heater switch, navigation light rheostats, oil dilution switch, rotating beacon swith, landing light switch, gear down indicator light, instrument and radio light rheostats. Electronic components are installed in the center panel between the pilot's and copilot's location.

A stack of three radios and/or radio direction finder equipment is located in this area. Under the radio is a nav-o-matic control auto pilot.

Electrical units on the right or copilot's side of the instrument panel are (1) a transponder control located on extreme right; (2) and ammeter; and (3) additional electrical units including cylinder head temperature gauge, oil temperature gauge, and cigar/cigarette lighter. In combination with these potential electric ignition sources are the fuel, oil, and hydraulic selector and sensor lines brought to the instrument panel for indication of flow and pressure. Additionally fuel flows through the cabin from the overhead wing tanks to the tank selector valves located between the pilot and copilot.

TEST RESULTS

Testing of hand fire extinguishers was conducted remotely and observed and recorded by video systems. All testing was conducted at an airspeed of 120 miles per hour (mph), as this condition was obtained with the tunnel drive engines and the Cessna 210 piston engine operating at cruise power. Testing was accomplished under two conditions of cabin ventilation. The overhead vents were opened to give ventilation air of 122 cubic feet per minute. This results in cabin air change time of appproximately 1 minute, as described in reference 1. The second condition was with the overhead vents closed. Copious ventilation is still present with the vents closed because of air leakage.

DISCHARGE UNDER THE INSTRUMENT PANEL.

Table 1 shows that 86.7 percent of cabin fires in general aviation aircraft are electrical in origin. This fire problem is for the most part located under the instrument panel. This area was addressed by eight extinguisher tests under the instrument panel. Two Halon 1301 and two Halon 1211 extinguishers were discharged under the instrument panel on the copilot's side and identical extinguishers were discharged uder the instrument panel on the pilot's side. One test with each agent was with air ventilation resulting from open overhead vents, and one test with each extinguisher was with the overhead vents closed.

The gas measurements for the tests conducted with extinguishers discharged under the instrument panel were plotted against time in seconds and are presented in figures 5 through 12, and certain selected values were tabulated in table 2.

Points from continuous data were selected by the computer and plotted at intervals of 1 second. Peak Halon 1301 concentrations behind the instrument panel ranged from 9.1 percent to 10.8 percent, and Halon 1211 concentrations varied from 8.1 percent to 11.0 percent. Halon 1301 concentrations at the pilot's nose height ranged from 1.5 percent to 5.2 percent, and Halon 1211 varied from 3.0 percent to 4.4 percent. Halon gas measurements were also recorded between the pilot and copilot at belt level. These data were obtained to answer the question as to what problems would occur if the pilot should bend over to check or adjust aircraft controls or check for fire extinguishment. Dose was calculated in accordance with references 3 and 4. The perfect stirrer theory predicts an expotential decay of extinguisher gases as time proceeds. From the maximum concentration at the starting point, the concentration will decay to 37 percent of the maximum after one air change, and to 5 percent of the maximum after three air changes. Examination of the Halon concentrations versus time measurements in this report demonstrate that the discrete data decayed in an exponential relationship. In addition, there was an initial rise time and in many instances after the rise, concentrations remained relatively constant for up to 10 seconds prior to exponential decay. This was due to the 10- to 14-second time internal for complete discharge of bottle content. These excursions were calculated separately and then added to the dose calculations.

Dose limits for the pilot was 4 percent extinguisher agent concentration over only 1 minute for the Halon 1211, and 10 percent for 1-minute Halon 1301 (reference 4).

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Dose limits for the pilot was 4 percent extinguisher agent concentration over only 1 minute for the Halon 1211, and 10 percent for 1-minute Halon 1301 (reference 4).

TABLE 2. DATA SUMMARY

Figure No.	Test Location	Agent Type	Agent Disch W Lbs	Agent Disch Time Sec	Ventilation Vents Open	Ventilation Vents Closed	Max Conc Test Location	Max Conc Pilot's Belt Level
5	Under Instru Panel Copilot	1301	3.1	11	X		9.4	--
6	Under Instru Panel Copilot	1301	3.0	-		X	10.8	4.5
7	Under Instru Panel Copilot	1211	2.5	11	X		11.0+	8.9
8	Under Instru Panel Copilot	1211	2.3	-		X	11.0+	10.5
9	Under Instru Panel Pilot	1301	3.2	14	X		9.1	9.1
10	Under Instru Panel Pilot	1301	3.1	13		X	9.3	9.7
11	Under Instru Panel Pilot	1211	2.9	12	X		8.1	8.0
12	Under Instru Panel Pilot	1211	2.8	11		X	10.5	8.0
13	Fuel & Hyd Selec Valv	1301	3.2	13	X		8.8	10.8
14	Fuel & Hyd Selec Valv	1301	3.2	13		X	11+	9.9
15	Fuel & Hyd Selec Valv	1211	2.9	12	X		9.2	6.6
16	Fuel & Hyd Selec Valv	1211	3.3	-		X	7.9	6.8
17	Copilot Dr Undr Arm Rest	1301	3.2	-	X		10.8	7.0
18	Copilot Door Undr Arm Rest	1301	3.2	-		X	9.0	9.1
19	Copilot Door Undr Arm Rest	1211	2.7	11	X		7.7	7.1
20	Copilot Door Undr Arm Rest	1211	3.0	13		X	7.6	5.2
21	Rear Seat Back Center	1301	3.2	15	X		11+	4.7
22	Rear Seat Back Center	1301	3.2	15		X	10.8	7.4
23	Rear Seat Rear Center	1211	2.7	10	X		6.4	2.6
24	Rear Seat Back Center	1211	2.8	11		X	6.9	-
25	Bagg Compr	1301	3.2	15	X		11+	3.6
26	Bagg Compr	1301	3.1	16		X	10.50	5.5
27	Bagg Compr	1211	2.8	-	X		9.3	2.0
28	Bagg Compr	1211	2.9	-		X	9.8	4.2

TABLE 2. DATA SUMMARY (Continued)

Figure No.	Max Conc Pilot Nose	Dose Pilot Belt	Dose Pilot Nose	Air Temp °F	Max Delta °F	Rel Humity %	Test No.
5	3.4	-	1.60	70.9	5	10	1
6	1.5	5.65	1.41	92.1	8		45
7	4.4	3.54	1.63	77.4	66.8	-	48
8	3.0	5.95	1.79	84.5	76.0	-	47
9	5.2	3.08	2.32	63.7	14.9	70	11
10	4.1	6.68	2.53	78.1	8.9	70	12
11	3.4	5.00	2.0	79.9	45.4	70	15
12	3.3	5.53	2.02	80.3	63.0	70	14
13	5.4	5.82	2.69	68.5	41.2	18	8
14	5.9	6.53	3.10	86.0	75.7	25	9
15	3.2	4.88	1.72	69.2	26.3	15	6
16	4.0	5.78	2.56	75.9	54.5	15	7
17	3.4	3.27	1.65	84.5	28.4	-	19
18	2.4	6.44	1.72	84.4	8.0	-	18
19	1.8	2.62	0.77	73.6	5.5	-	16
20	1.5	3.70	0.66	80.3	79.0	-	17
21	3.5	1.68	1.35	99.8	84.2	-	20
22	4.3	4.60	2.26	85.6	83.2	-	21
23	2.0	0.88	0.62	91.3	13.0	-	23
24	2.7	-	1.33	101.1	29.0	-	22
25	3.3	1.65	1.54	73.1	25.0	25	27
26	2.5	4.93	1.48	68.0	12.3	30	26
27	1.1	0.76	0.34	66.8	15.7	-	24
28	1.6	2.20	0.64	75.9	23.1	26	25

The maximum dose calculated from the test results for Halon 1211 was only 50 percent of the limit, and the maximum dose for Halon 1301 was 25 percent of the limit at the pilot's nose. The pilot could bend over the 11 seconds without exceeding the limit dose when discharging Halon 1211 extinguishers of 2.5-pound capacity, and may bend over for an unlimited time period for discharge of Halon 1301 of 3-pound capacity.

DISCHARGE TO FUEL AND HYDRAULIC SELECTOR VALUES.

The extinguishers were directed to the fuel and hydraulic selector valves located on a console raised approximately 6 inches from floor between the pilot and copilot. Two 2.5-pound Halon 1211 extinguishers and two 3.0-pound Halon 1301 extinguishers were tested with identical ventilation conditions as previously described. The gas measurements are plotted in figures 13 through 16 and selected data are tabulated in table 2. Dose calculated for the pilot's nose was 1.72 and 2.56 percent minutes and is up to 64 percent of the limit for Halon 1211 and 2.69 and 3.10 for Halon 1301 which is 31 percent of the limit dose. Maximum dose at the pilot's and copilot's belt level was 4.88 and 5.78 percent minutes for Halon 1211 and 5.82 and 6.53 of Halon 1301. The pilot could bend over the 10 seconds without exceeding the limit dose when discharging Halon 1211 and could bend over indefinitely after discharging Halon 1301.

DISCHARGE TO COPILOT'S DOOR.

Two Halon 1211 and two Halon 1301 extinguishers were discharged to the copilot's door at a point below the arm rest. Figures 17 through 20 show the agent concentrations plotted against time. As the discharge location was moved in relation to the pilot, dose calculations are less. The dose for the pilot was only 19 percent of the limit for Halon 1211, and 17 percent of the limit for Halon 1301.

DISCHARGE TO REAR SEAT BACK.

Two Halon 1211 and two Halon 1301 bottles were discharged to the center of the rear seat back. The measurements plotted versus time are in figures 21 through 24 and values are tabulated in table 2. Dose calculations for the pilot's nose was only up to 33 percent of the limit for Halon 1211 and up to 23 percent of the limit for Halon 1301. Dose for the pilot's belt level was also low and was below the limit dose for both agents.

DISCHARGE TO BAGGAGE COMPARTMENT.

Extinguishers were directed to the center section of the baggage compartment. Tests of both Halon 1211 and Halon 1301 extinguishers were completed. The measurements are plotted in figures 25 through 28 and selected values are tabulated in table 2. The dose calculations for the pilot's nose was only 16 percent of the limit for Halon 1211, and only up to 15 percent of the limit for Halon 1301. Dose for the pilot's belt level was also low and was below the limit dose for both agents.

RESULTS.

Summaries of neat Halon extinguisher tests are contained in table 2. Relevant information includes the figure number and test location and type of Halon extinguisher. Agent discharge time were determined was possible from video records.

Ventilation conditions during the tests of overhead vents open or closed are described.

The maximum concentrations of neat extinguisher gases are listed for the three sample locations; pilot's nose, pilot-copilot belt level, and in proximity to extinguisher discharge. Dose calculations are tabulated for the pilot's belt level and for the pilot's nose. The cabin air temperature and the maximum reduction in air temperature in proximity to extinguisher discharge are listed. Finally, the relative humidity and the test number are included. The weight of agent discharged averaged 2.8 pounds for Halon 1211 and weight of Halon 1301 agent discharged averaged 3.16 pounds. Discharge time was 11.38 seconds and 13.89 seconds for Halon 1211 and Halon 1301 extinguishers, respectively.

The effect of cabin ventilation conditions with overhead vents open and vents closed are listed for dose calculations for both extinguishers in table 3. Dose was increased significantly with the vents closed. At the pilot-copilot belt level location, dose increased 57 to 87 percent with the vents closed compared with the vents opened. While at the pilots nose, dose increased 12 to 27 percent under similar conditions. When maximum concentrations were compared, only minimal increases were measured with the vents closed. Since the dose calculations are based on the area under the concentration curves, it was concluded that dissipation or decay occured over longer time periods when the vents were closed. The concentrations of Halon 1301 were increased somewhat over Halon 1211, and reflected the increased agent charge weight of 3 pounds as compared to 2.5 pounds.

TABLE 3. VENTILATION RESULTS

Sample Location	Ventilation Open	Ventilation Closed	Sample Size	Mean Dose Percent Increase
Pilot-Copilot Belt Level				
Halon 1211	X		6	-
Halon 1211		X	6	57
Halon 1301	X		5	-
Halon 1301		X	6	87
Pilot's Nose Height				
Halon 1211	X		6	-
Halon 1211		X	6	27
Halon 1301	X		6	-
Halon 1301		X	6	12

EXTINGUISHER AGENT DISTRIBUTION UNDER INSTRUMENT PANEL.

An investigation was conducted to determine the distribution of extinguisher agents under the instrument panel. The gas sample lines were arranged to sample near the top of the instrument panel (pilot's side), near the top of the instrument panel (copilot's side), and at the very low center section under the stack of radios and direction finding electronics. The measurements are plotted versus time, figures 29 through 32, and selected values are listed in table 4. One Halon 1211 extinguisher and one 1301 extinguisher were discharged under the instrument panel on the copilot's side and identical testing was completed by discharging the extinguishers under the instrument panel pilot's side. High levels of agent (10 to 11 percent) were measured under the instrument panel on the side where the extinguishers were discharged. On the opposite side of the instrument panel, extinguisher gas concentrations ranged from 3.8 percent to 4.5 percent. Under the stack of radios located in the center section, concentrations ranged from high levels to low levels of 3.8 percent. Thus, both agents exhibited good distribution throughout the sampled area beneath the instrument panel.

EXTINGUISHER AGENT STRATIFICATION IN CABIN.

Testing was designed to measure extinguisher agent stratification within the cabin. The three sample lines were placed on the cabin floor. Single sample lines were placed on the floor both near the pilot and the copilot and on the floor by the rear passenger behind the pilot. The measurements are in figures 33 and 34 and selected values are listed in table 5. The highest Halon extinguisher gas concentrations are located on the floor. In all cases, the gas measurement capability was overwhelmed and exceeded the maximum measurement level of 11 percent. Stratification of the Halon agents are presented in figure 35. Average gas measurements were plotted for the pilot-copilot belt level and for the pilot's nose location. As noted, only one test with each Halon was conducted for measurement of the agents for the floor. Stratification of the Halons is significant as they vary from over 11 percent on the floor to 2.65 percent and 4.03 percent at the pilot's nose and it appears that this relationship is near linear, figure 35.

TABLE 4. EXTINGUISHER GAS DISTRIBUTION

Figure No.	Discharge Location	Agent Type	Agent Disch W Lbs	Agent Disch Time Sec	Max Conc Pilot's Side %	Max Conc Copilot's Side %	Max Conc Center Radios %
29	Under Instr Pan Copilot's Side	1301	2.7	-	4.3	11+	10.8
30	Under Instr Pan Copilot's Side	1211	2.4	11	4.5	7.9	9.9
31	Under Instr Pan Pilot's Side	1301	-	12	10.5	0.9	3.8
32	Under Instr Pan Pilot's Side	1211	2.3	13	11.0	0.5	4.3

TABLE 5. EXTINGUISHER GAS STRATIFICATION

Figure No.	Sample Location	Agent Type	Agent Disch W Lbs	Agent Disch Time Sec	Max Conc On Floor By Pilot	Max Conc On Floor By Copilot	Max Conc On Floor By Rear Seat
33	Sample Lines On Floor	1301	2.5	12	11+	11+	11+
34	Sample Lines On Floor	1211	2.4	11	11+	11+	-

SUMMARY OF RESULTS

Hand fire extinguishers charged with Halon 1211 and Halon 1301 of 2.5 pound and 3-pound capacity, respectively, were tested and evaluated in a Cessna 210C airplane. Four mannequins were used for pilot and passengers and baggage was placed in the baggage compartment. These tests were conducted in an airflow facility without fires and involved the continous sampling and measurement of neat Halon gases from three locations. The agent concentrations were measured in proximity to discharge of the extinguishers at the pilot and copilot belt level, and at the pilot's nose. Air temperature was measured near discharge of the extinguishers and at the pilot's nose. Testing was completed for ventilation conditions of overhead vents open and overhead vents closed. Two Halon 1211 and two Halon 1301 extinguishers were discharged at each test location. Agent discharge was mainly under the instrument panel because cabin fire statistics show that 87 percent of cabin fires in general aviation aircraft are electronic or electrical in origin. Additional test locations include the fuel and hydraulic selector valves, the copilot's door, the rear seat, and the baggage compartment.

Extinguisher agent concentrations near the point of extinguisher discharge ranged between 8 and 9 percent for Halon 1211, and averaged above 10 percent for Halon 1301. Near the pilot-copilot belt level, Halon 1211 extinguisher agent averaged about 6 percent and from 7.0 to 7.7 percent for Halon 1301, and dose for both extinguishers at this location averaged somewhat over 2.3 percent-minutes to 3.0 percent-minutes. Agent concentrations at the pilot's nose height averaged between 2.6 to slightly over 4.0 percent and dose averaged from about 1.0 to 1.5 percent minutes. Extinguisher gases usually dissipated to low levels in less than 1 minute. The utilization of four mannequins or test dummies for the cabin seating arrangement and placement of baggage in the baggage compartment caused somewhat higher gas concentrations and somewhat higher dose calculations than those measurements documented in reference 1. The use of Halon extinguishers of 2.5-pound and 3.0-pound capacity were demonstrated to be safe for use in the test aircraft as maximum dose was only 60 percent of the limit. Measurements were recorded to investigate distribution of extinguisher gases under the instrument panel. When extinguishers were discharged either on the copilot's side or pilot's side, high levels were measured on the discharge side and about 4.0 percent gas

concentration was measured on the opposite side of the instrument panel. Stratification of extinguisher gases in the cabin was determined. The three sample lines were placed on the cabin floor. High measurements in excess of 11 percent maximum were obtained in all locations.

CONCLUSIONS

1. Halon 1211 extinguishers of 2.5-pound capacity are safe for use in small general aviation aircraft. Halon 1301 extinguishers of 3.0-pound capacity are safe for use in small general aviation aircraft. Maximum dose calculations for neat Halon 1211 gases were only 60 percent of the recommended human exposure limits. Maximum dose calculations for neat Halon 1301 gases were only 30 percent of the recommended human exposure limits.

2. Extinguisher agent stratification and normal flight ventilation are major factors in producing safe conditions in the cabin at the pilot's nose level.

REFERENCES

1. Slusher, G. R., Wright, J., Demaree, J. E., and Neese, W. E., Extinguisher Agent Behavior in a Ventilated Small Aircraft, DOT/FAA/CT-83/30, January 1984.

2. NFPA 12A Halon 1301 Fire Extinguishing Systems and NFPA 12B Halon 1211 Fire Extinguishing Systems, National Fire Protection Association.

3. Hand Fire Extingusher for Use in Aircraft, Advisory Circular, AC No.; 20-42C, U.S. Department of Transportation, Federal Aviation Administration, 1984.

4. Eklund, T. I., Analysis of Dissipation of Gaseous Extinguisher Agents in Ventilated Compartments, DOT/FAA/CT-83/1, May 1883.

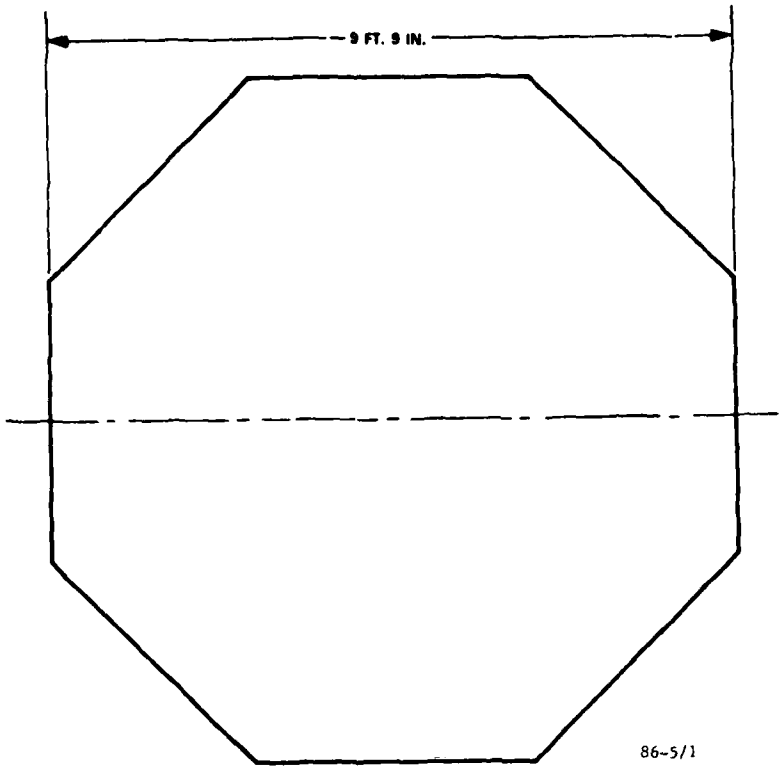


FIGURE 1. GENERAL AVIATION AIRFLOW FACILITY TEST SECTION - CROSS SECTION

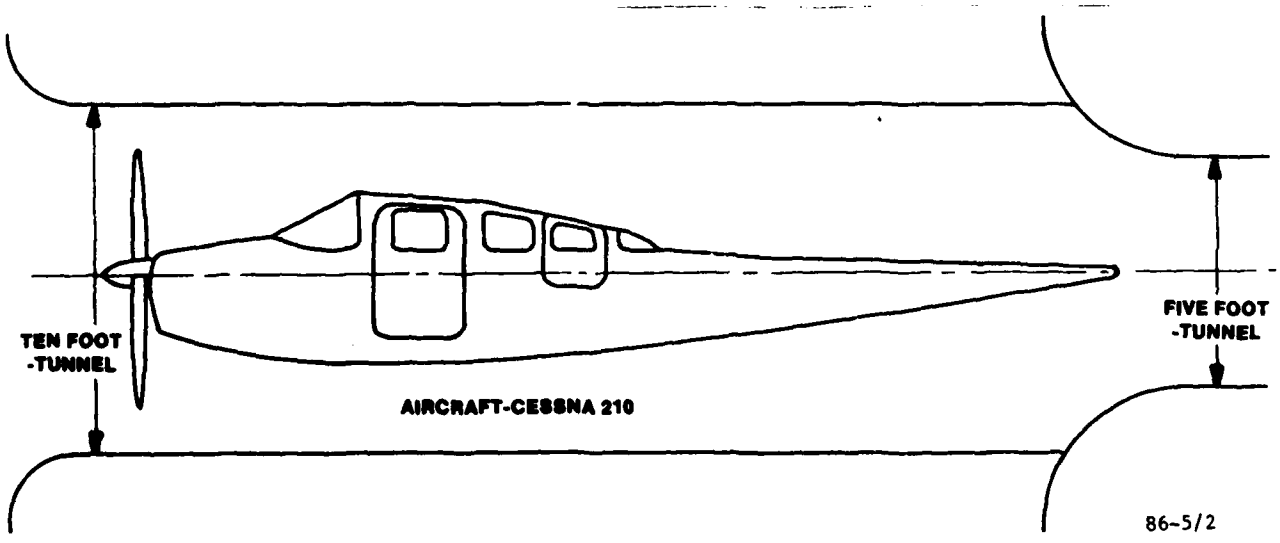
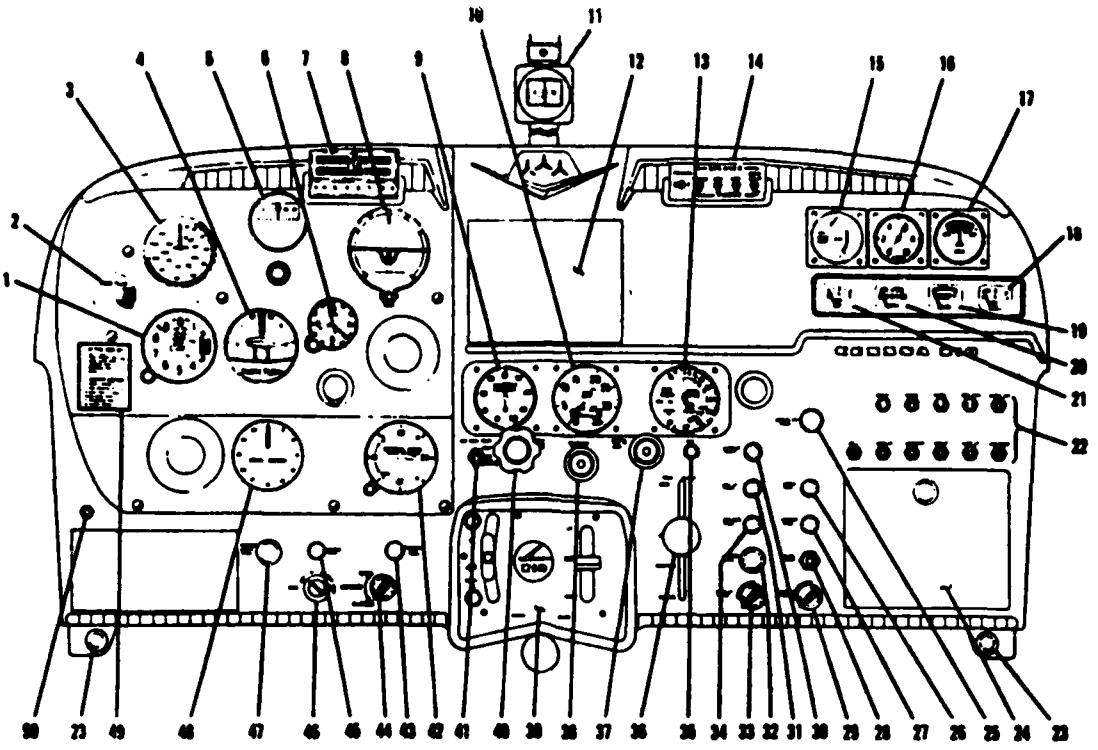


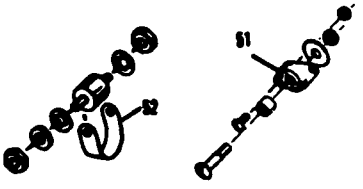
FIGURE 2. GENERAL AVIATION AIRFLOW FACILITY TEST SECTION - PROFILE

FIGURE 3. CESSNA 210C AIRPLANE WITHIN AVIATION FLOW FACILITY TEST SECTION



NOTE

If shockmount has unequal thread length, install shorter threads through stationary panel.



NOTE

The 210 and 210A instrument panels are identical except for minor styling changes and switch relocations.

1. Altimeter
2. Wing Flap Position Indicator
3. Airspeed Indicator
4. Turn-and-Bank Indicator
5. Directional Gyro
6. Clock
7. Compass Correction Card
8. Gyro Horizon
9. Manifold Pressure Gage
10. Tachometer
11. Magnetic Compass
12. Radio Space
13. Fuel Flow Indicator
14. Radio Selector Switches
15. Cylinder Head Temp. Gage
16. Suction Gage
17. Ammeter
18. Fuel Quantity Indicator
19. Oil Temperature Gage
20. Oil Pressure Gage
21. Fuel Quantity Indicator
22. Circuit Breakers
23. Cabin Air Knob
24. Map Compartment
25. Cabin Heat Knob
26. Radio Switch
27. Pitot Heater Switch
28. Oil Dilution Switch
29. Radio Light Rheostat
30. Landing Light Switch
31. Navigation Light Switch
32. Cigar Lighter
33. Instrument Light Rheostat
35. Generator Warning Light
36. Cowl Flap Lever
37. Mixture Control
38. Propeller Control
39. Power Pack (See Section 8)
40. Throttle
41. Auxiliary Fuel Pump Switch
42. Vertical Speed Indicator
43. Induction Hot Air Knob
44. Defrost Knob
45. Master Switch
46. Ignition - Start Switch
47. Fuel Strainer Drain Knob
48. Radio Compass
49. Check List
50. Microphone Jack
51. Shock Mount
52. Ground Strap

83-30-4

FIGURE 4. INSTRUMENT PANEL - CESSNA MODEL 210C AIRPLANE

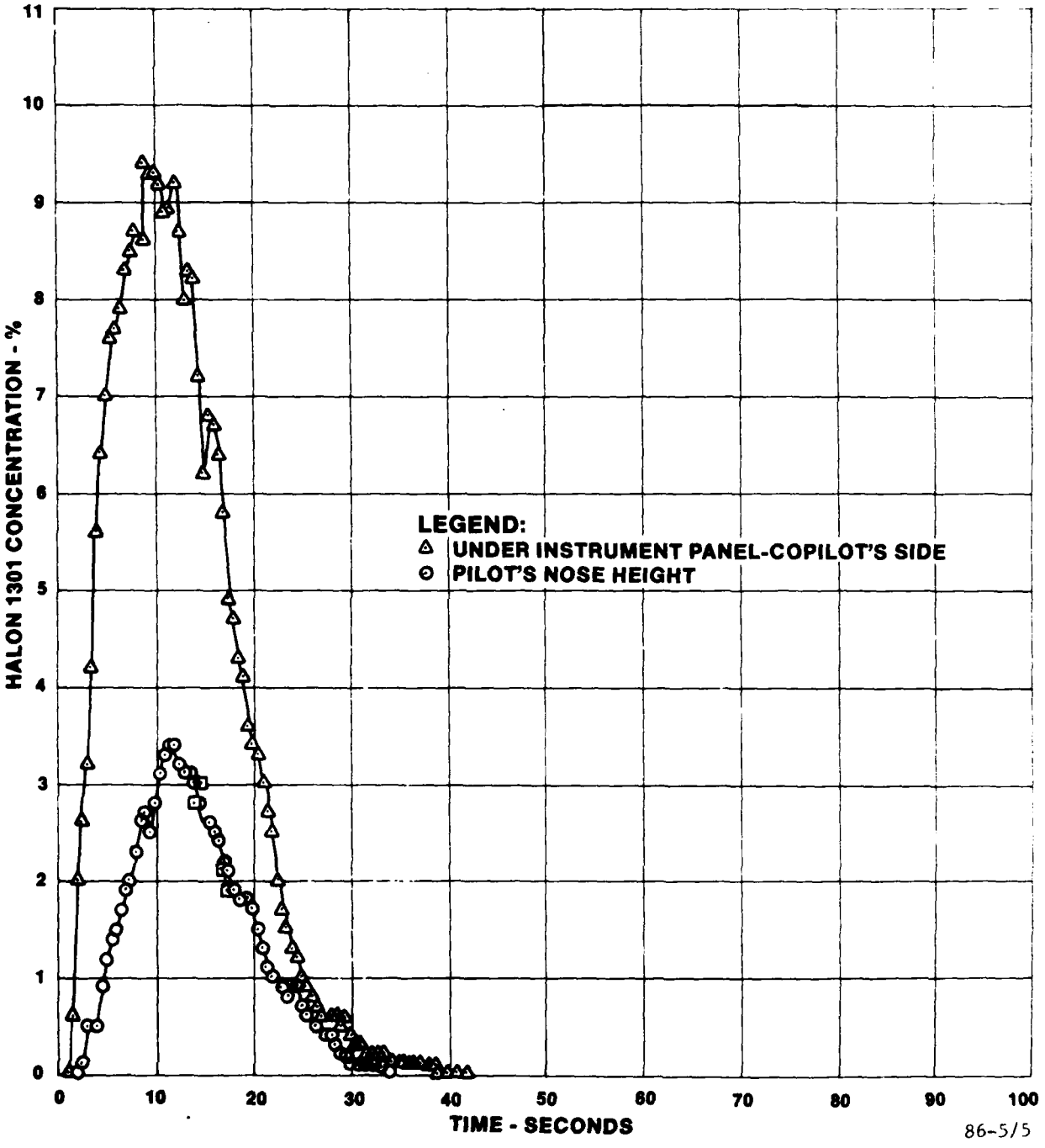


FIGURE 5. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - COPILOT'S SIDE - OVERHEAD VENTS OPEN

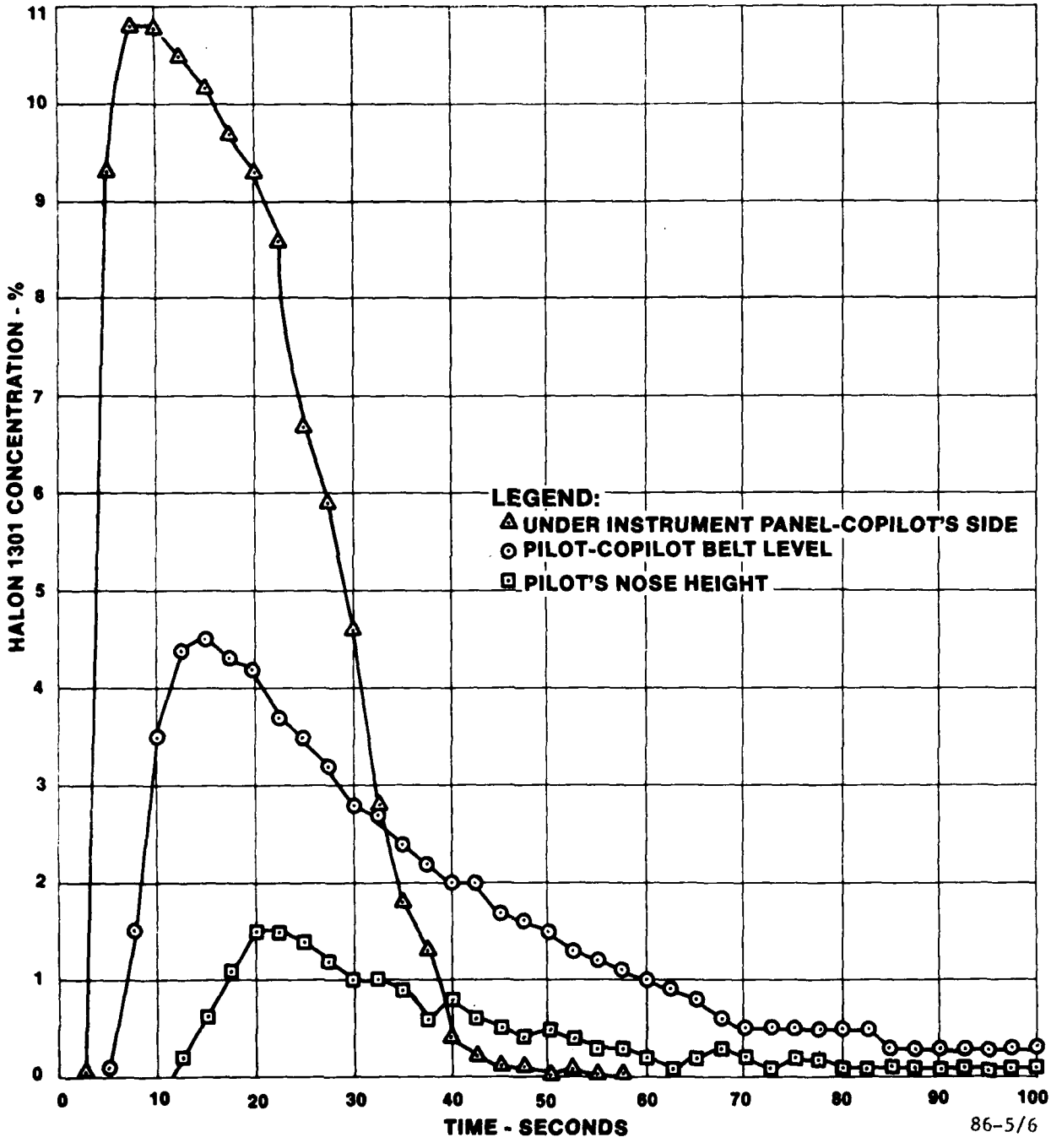


FIGURE 6. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - COPILOT'S SIDE - OVERHEAD VENTS CLOSED

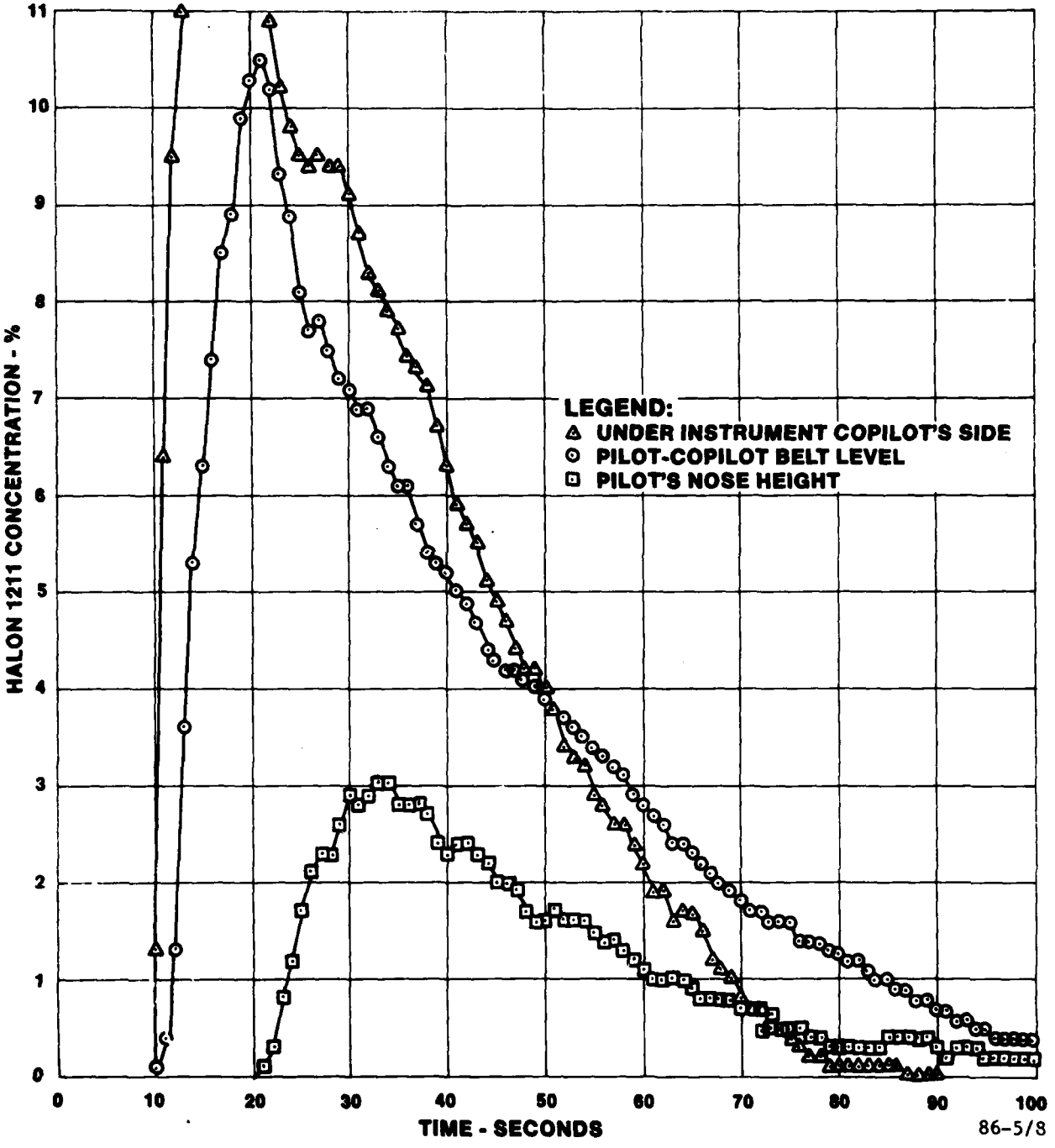


FIGURE 8. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - COPILOT'S SIDE - OVERHEAD VENTS CLOSED

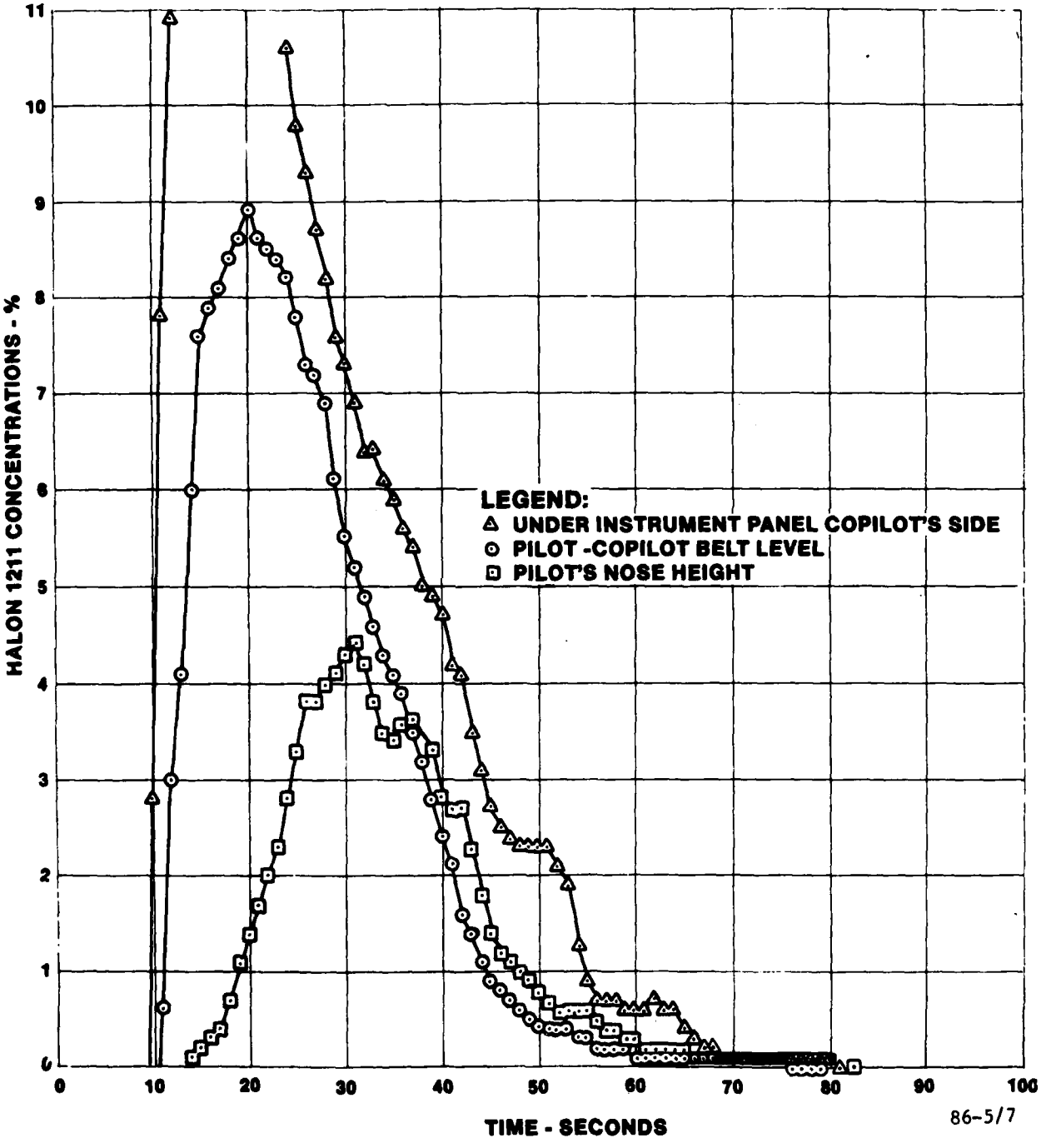


FIGURE 7. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - COPILOT'S SIDE - OVERHEAD VENTS OPEN

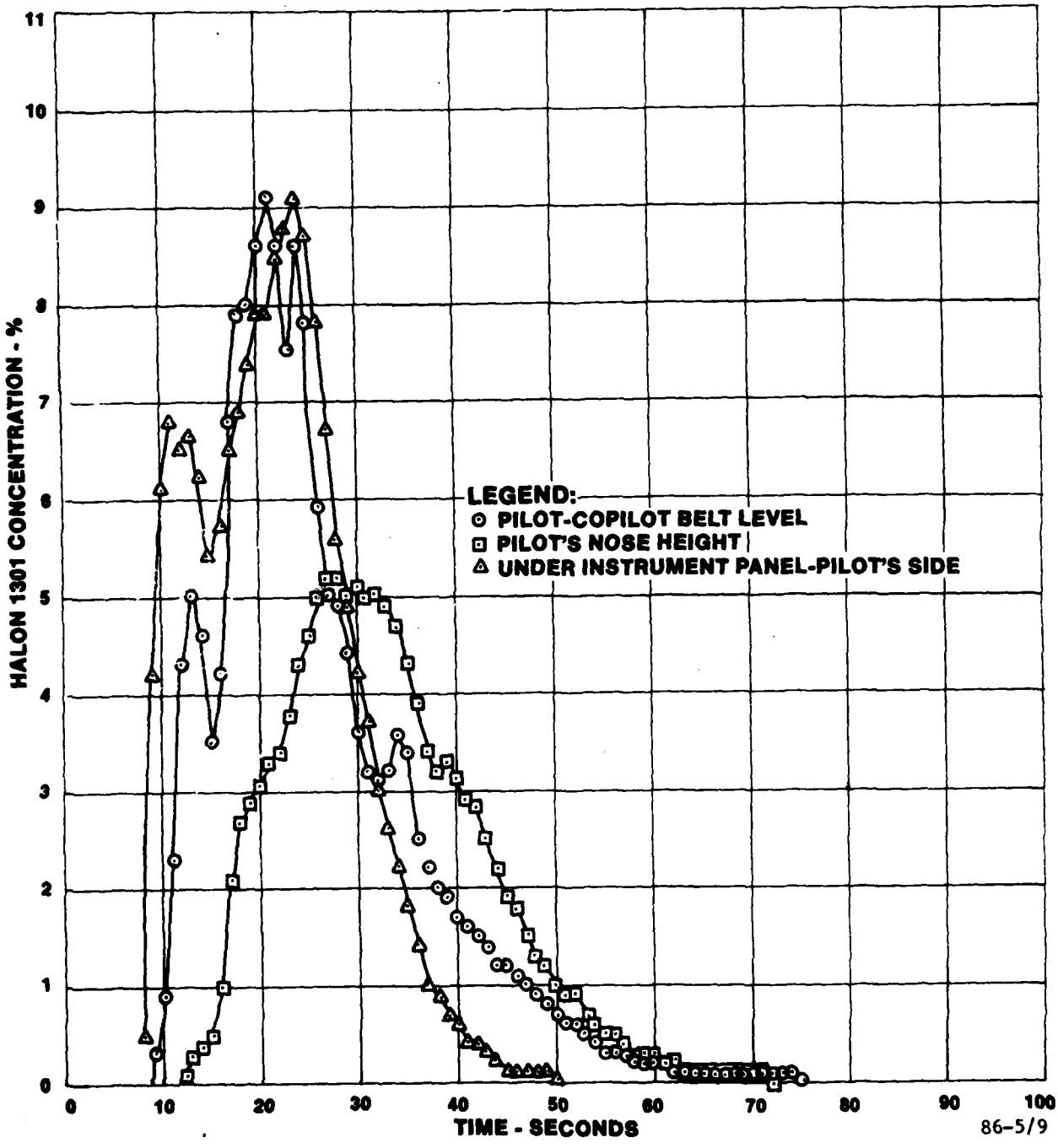


FIGURE 9. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - PILOT'S SIDE - OVERHEAD VENTS OPEN

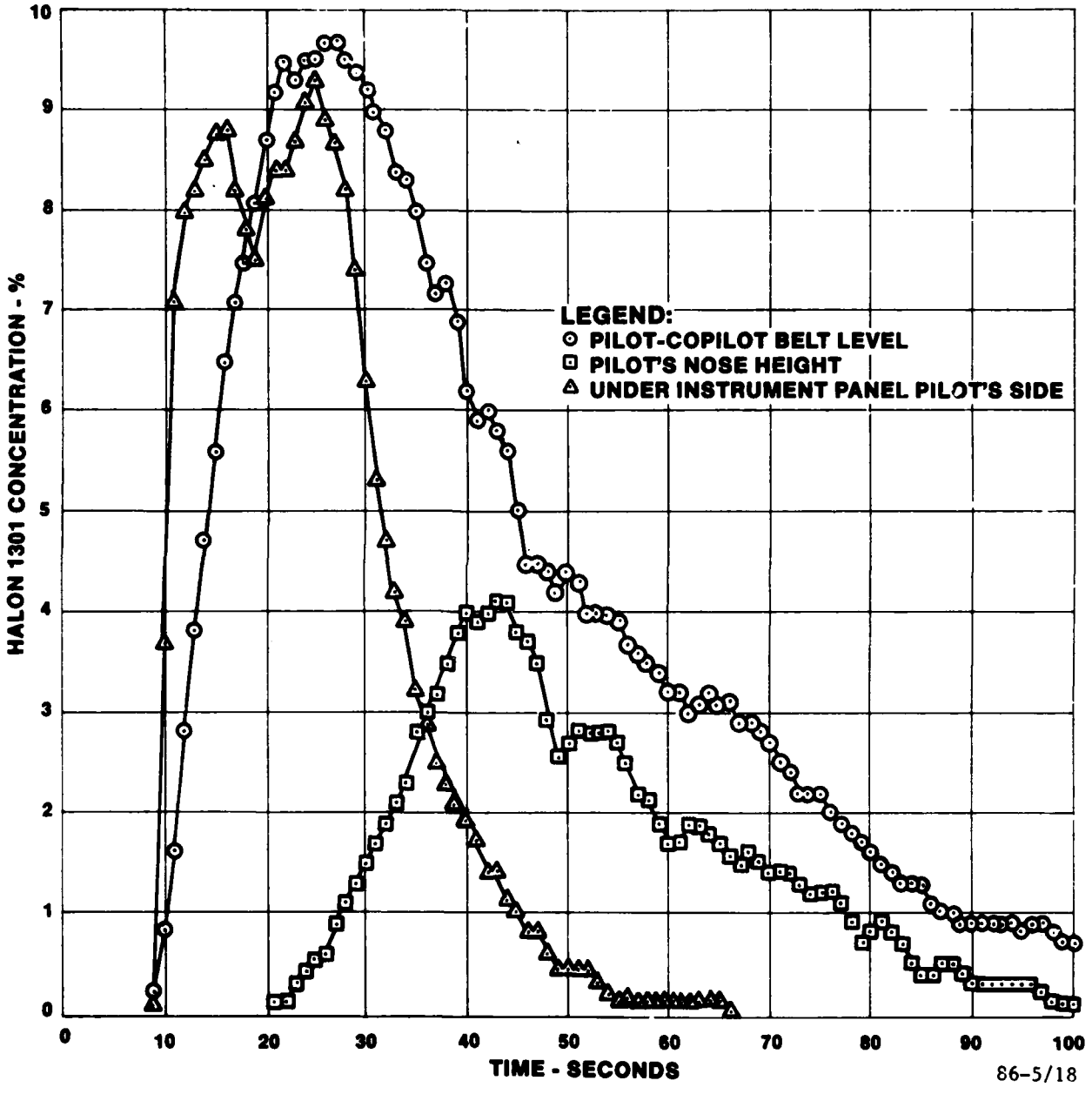


FIGURE 10. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE COPILOT'S DOOR - OVERHEAD VENTS CLOSED

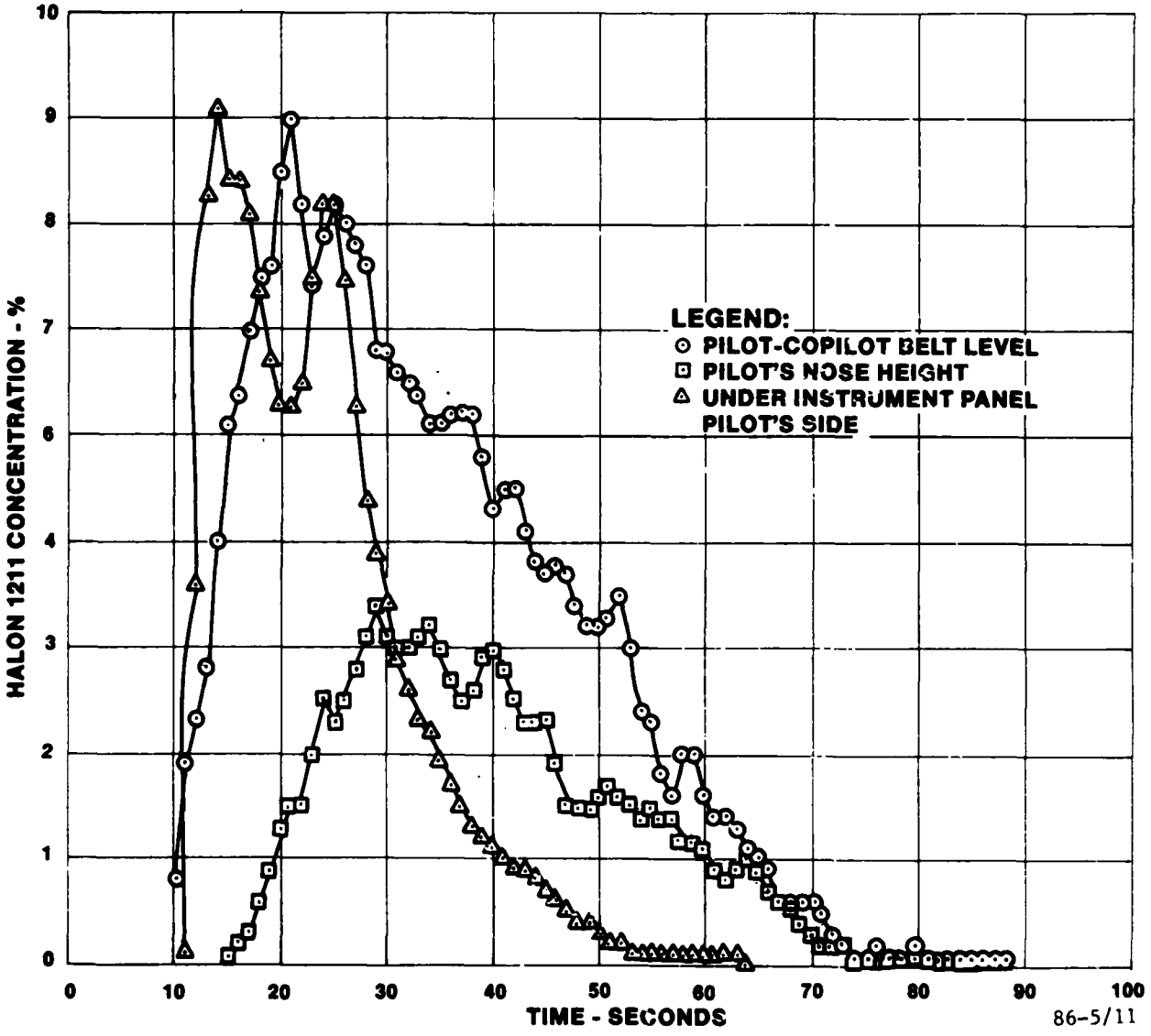


FIGURE 11. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - PILOT'S SIDE - OVERHEAD VENTS OPEN

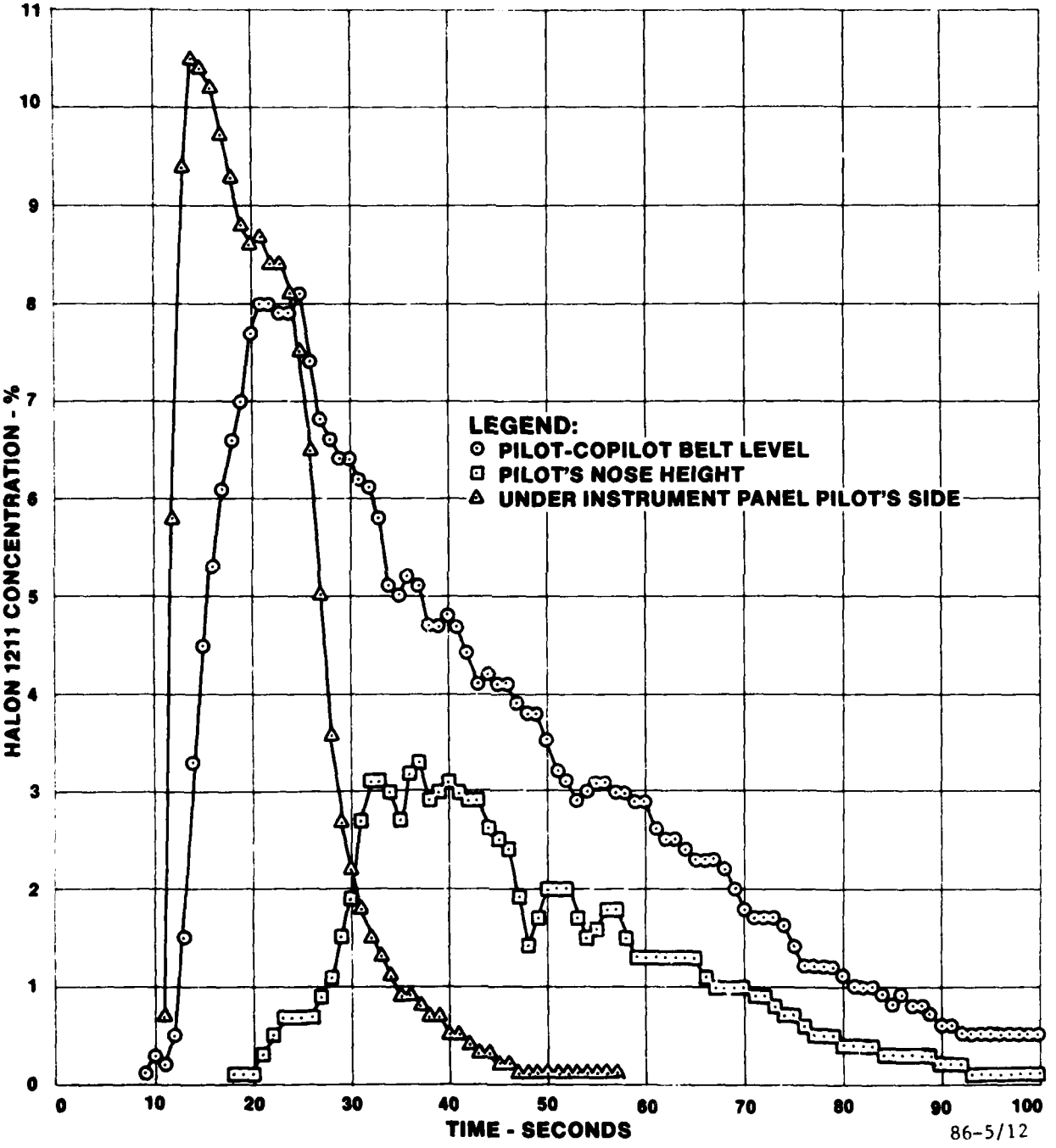


FIGURE 12. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - PILOT'S SIDE - OVERHEAD VENTS CLOSED

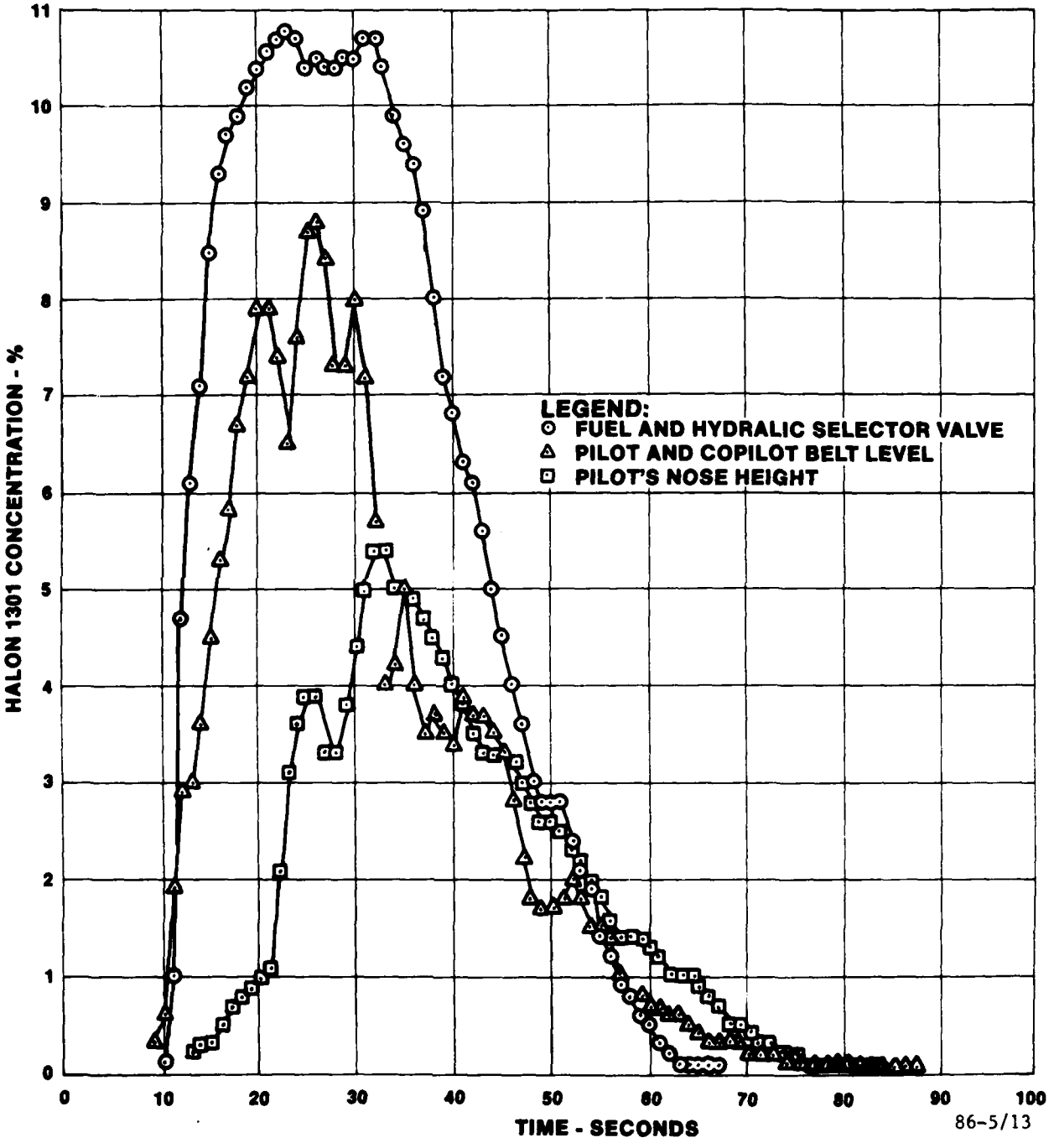


FIGURE 13. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE FUEL AND HYDRAULIC SELECTOR VALVES - OVERHEAD VENTS OPEN

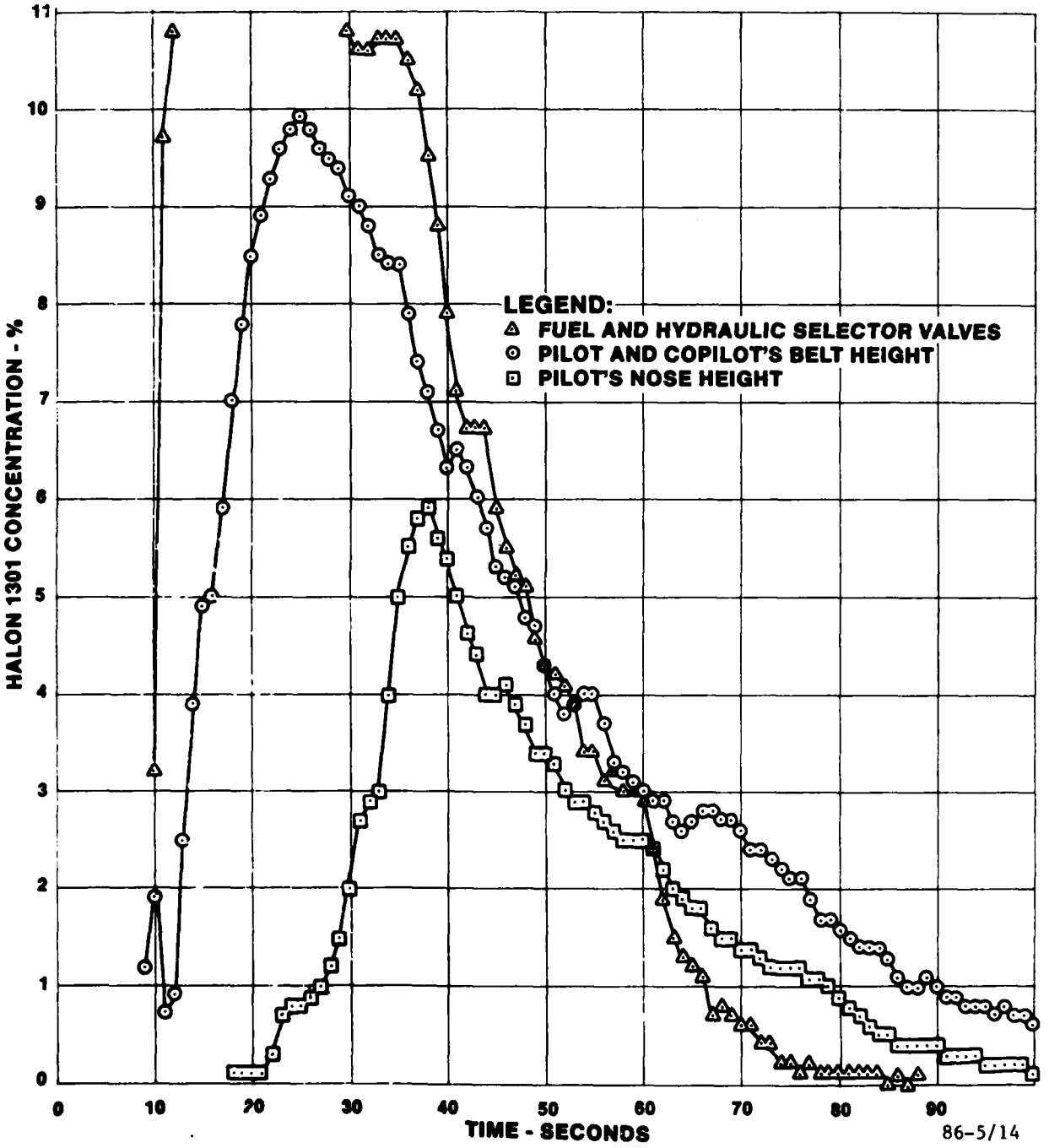


FIGURE 14. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE FUEL AND HYDRAULIC SELECTOR VALVES - OVERHEAD VENTS CLOSED

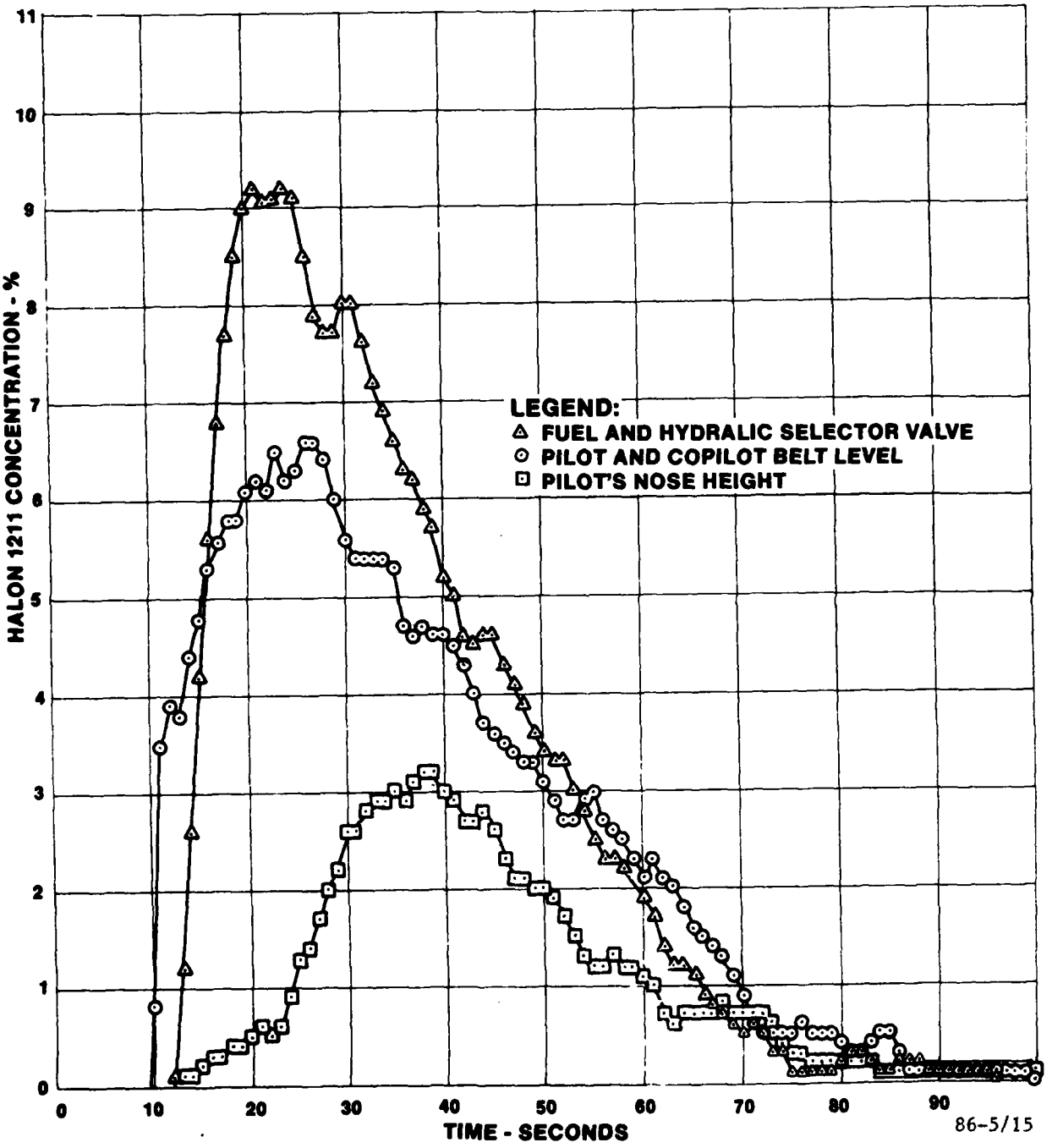


FIGURE 15. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE FUEL AND HYDRAULIC SELECTOR VALVES - OVERHEAD VENTS OPEN

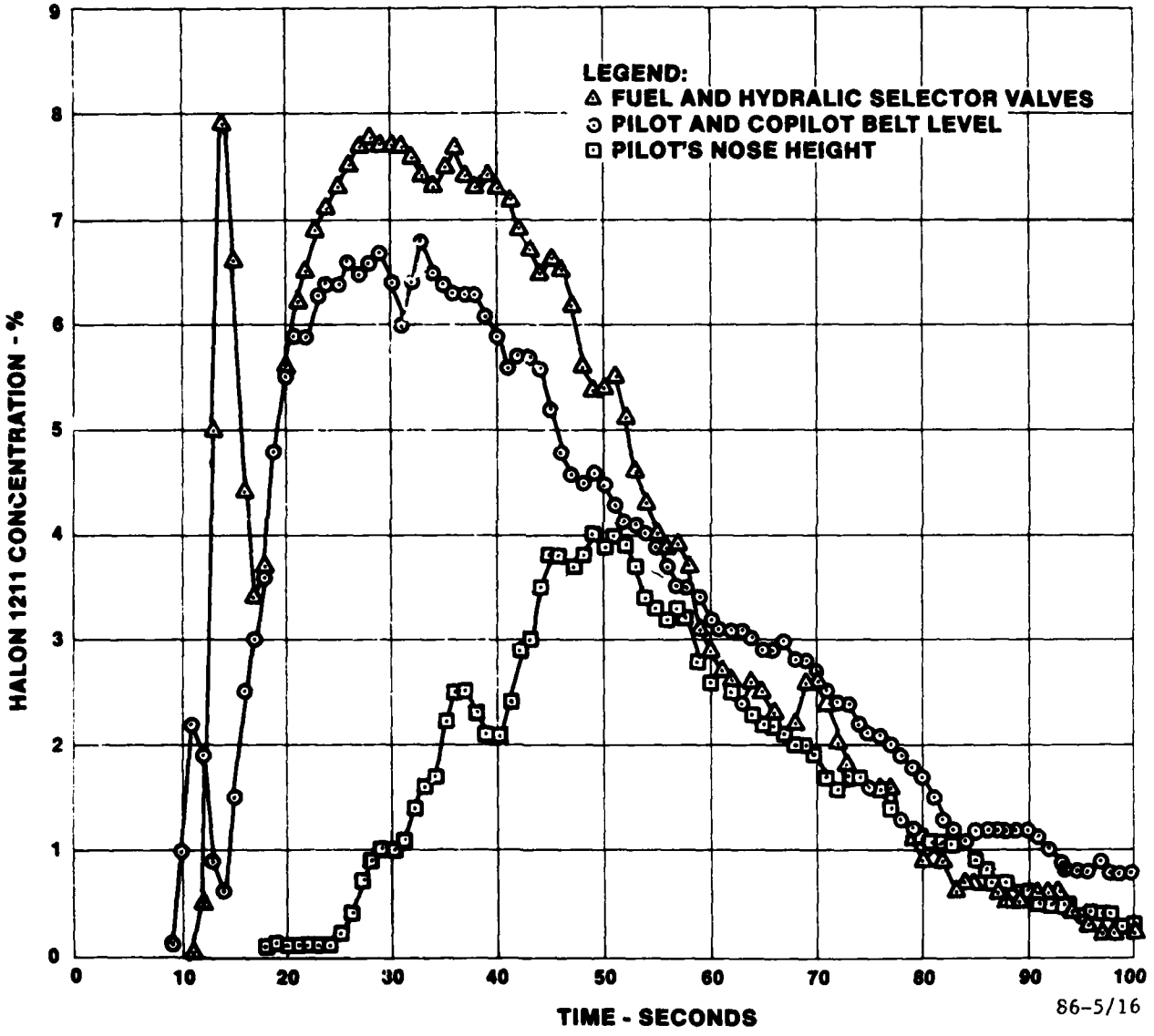


FIGURE 16. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE FUEL AND HYDRAULIC SELECTOR VALVES - OVERHEAD VENTS CLOSED

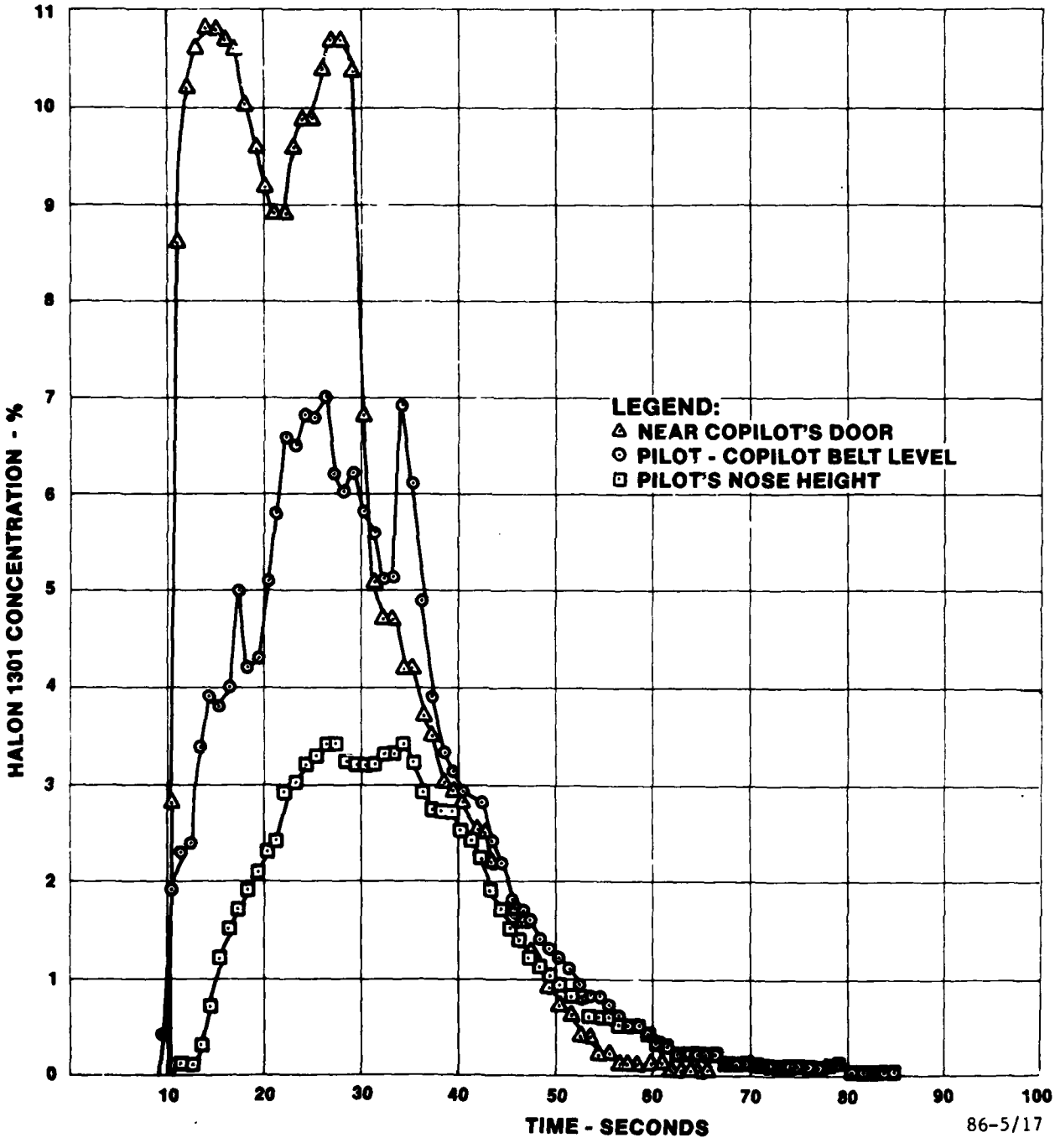


FIGURE 17. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE COPILOT'S DOOR - OVERHEAD VENTS OPEN

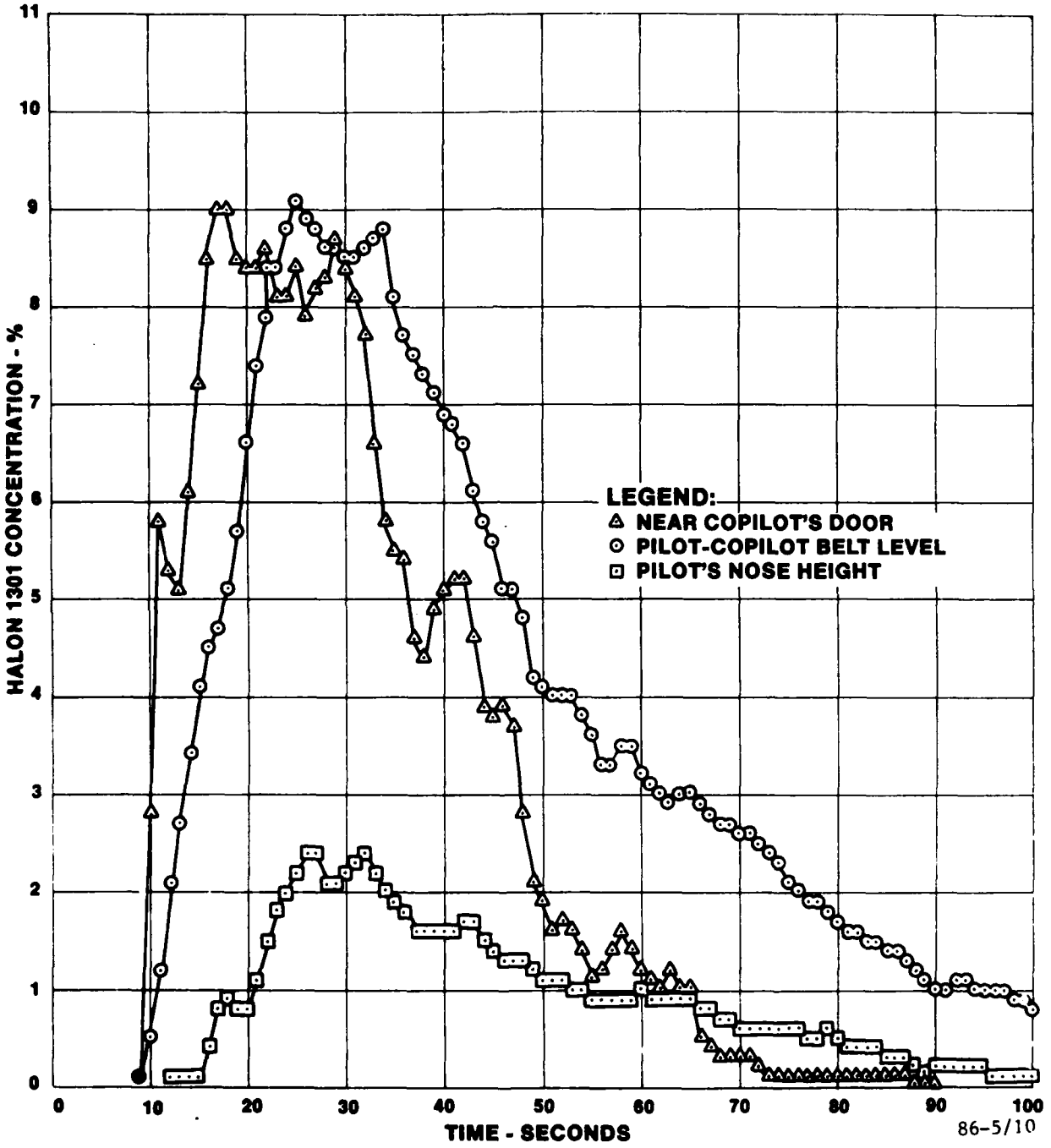


FIGURE 18. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED UNDER INSTRUMENT PANEL - PILOT'S SIDE - OVERHEAD VENTS CLOSED

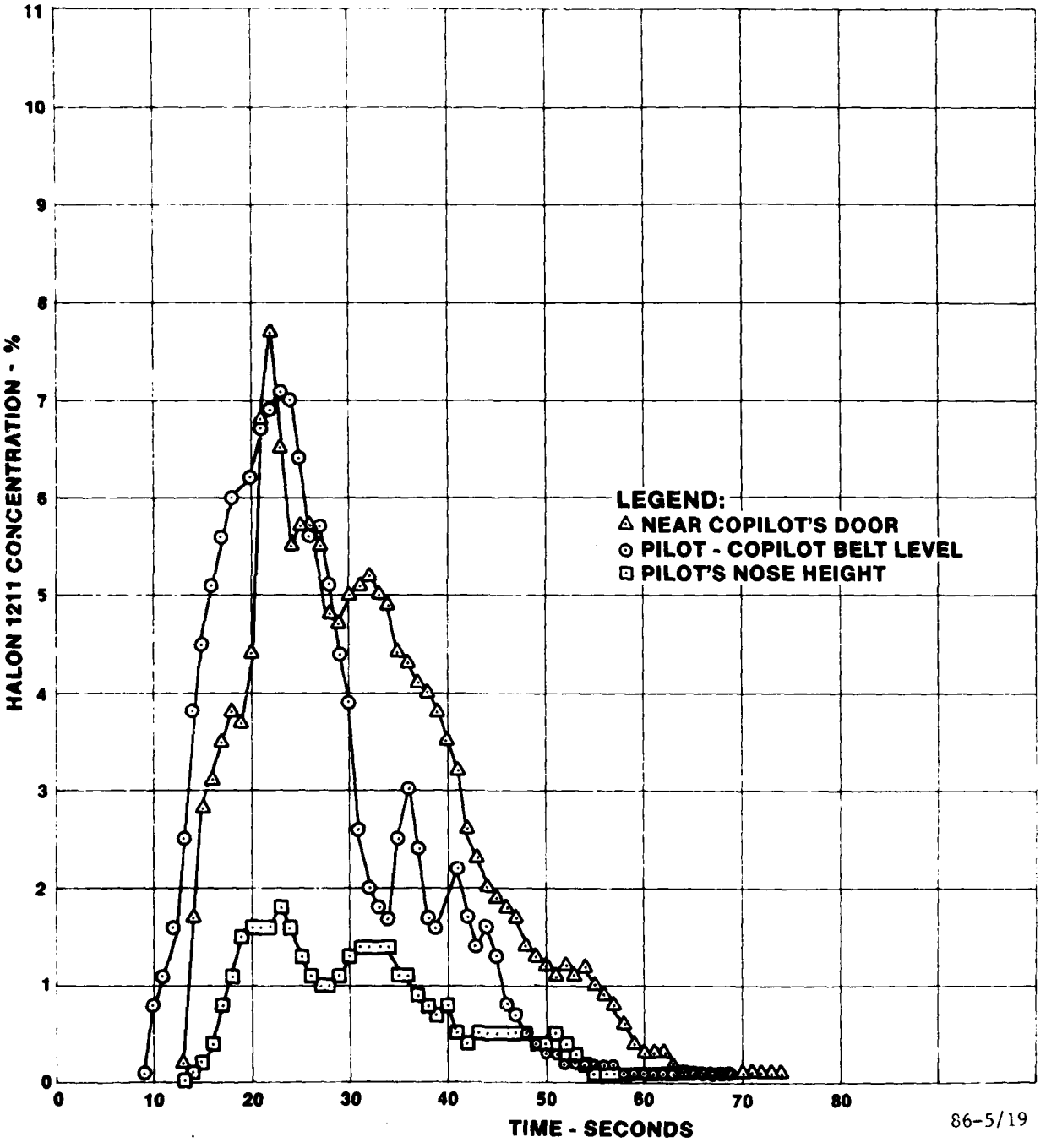


FIGURE 19. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE COPILOT'S DOOR - OVERHEAD VENTS OPEN

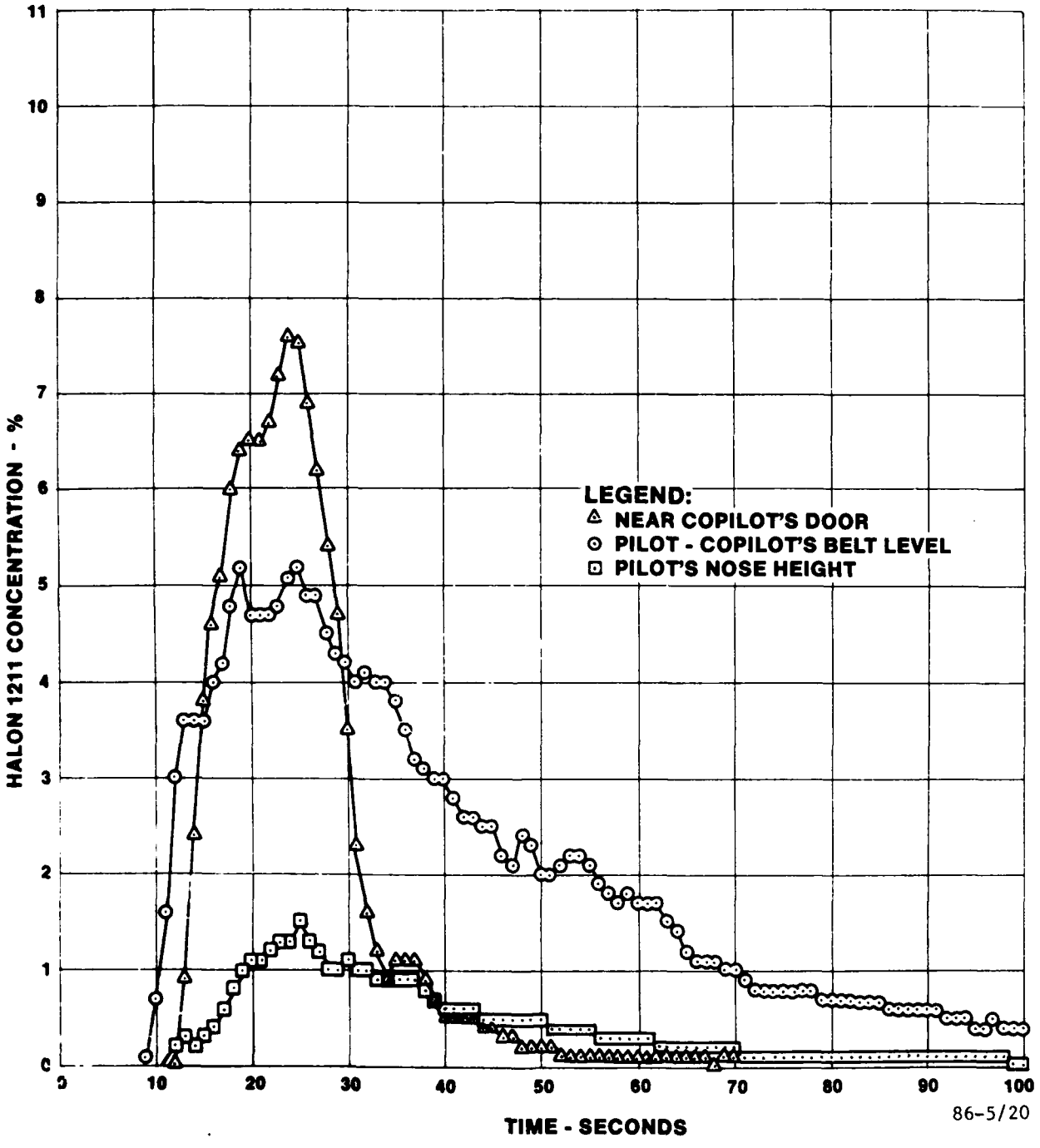


FIGURE 20. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE COPILOT'S DOOR - OVERHEAD VENTS CLOSED

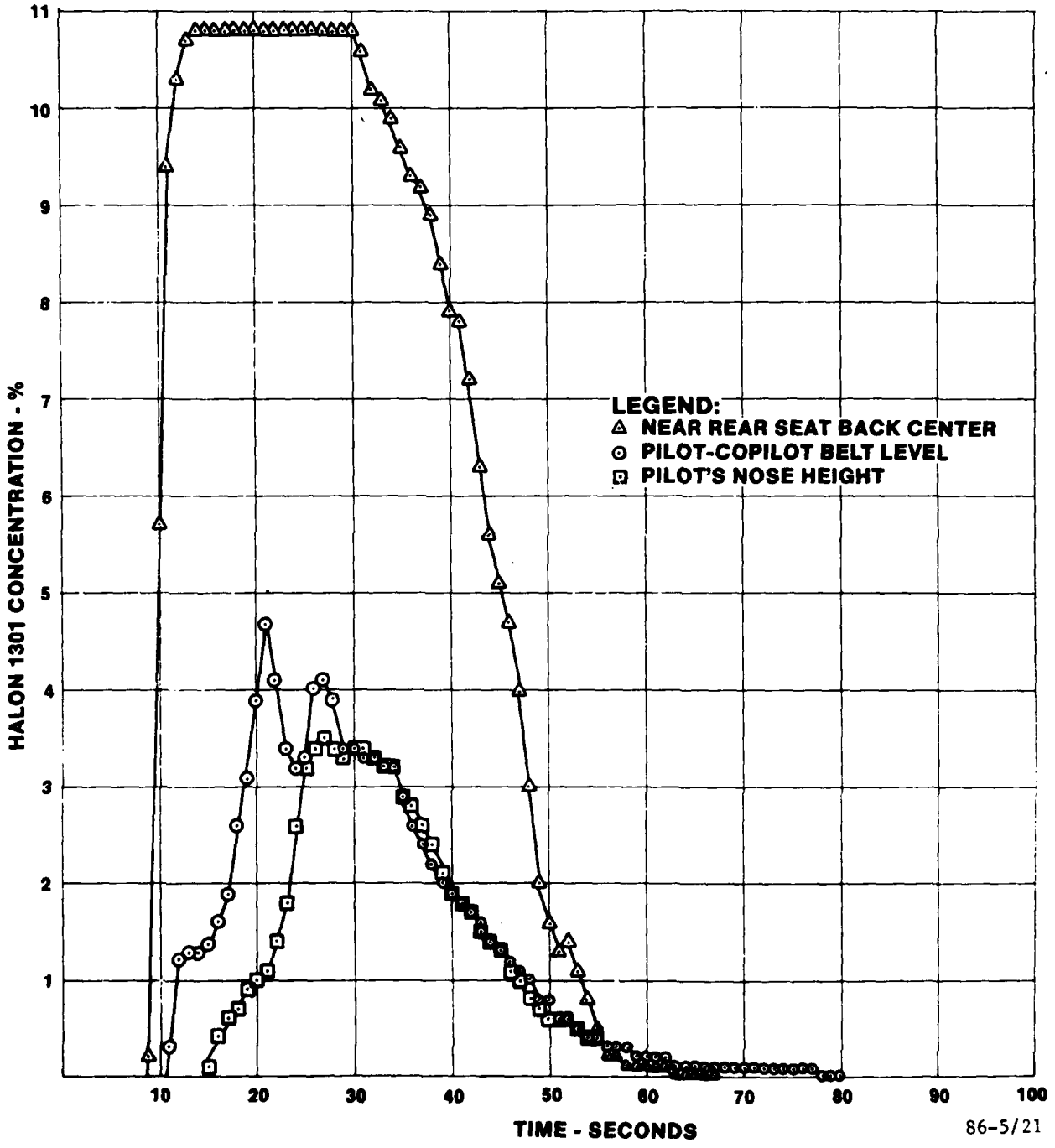


FIGURE 21. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE REAR SEAT - OVERHEAD VENTS OPEN

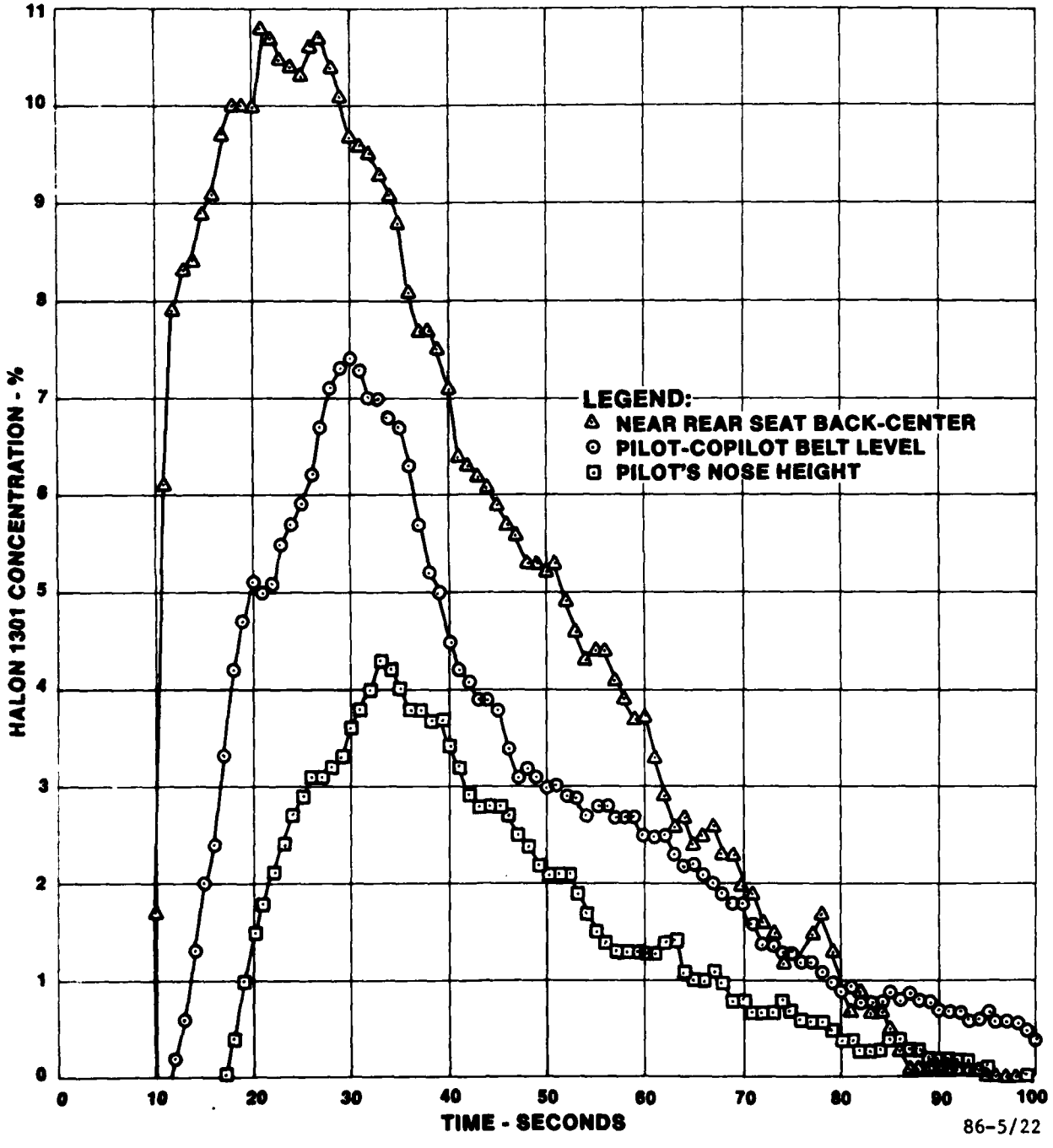


FIGURE 22. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE REAR SEAT - OVERHEAD VENTS CLOSED

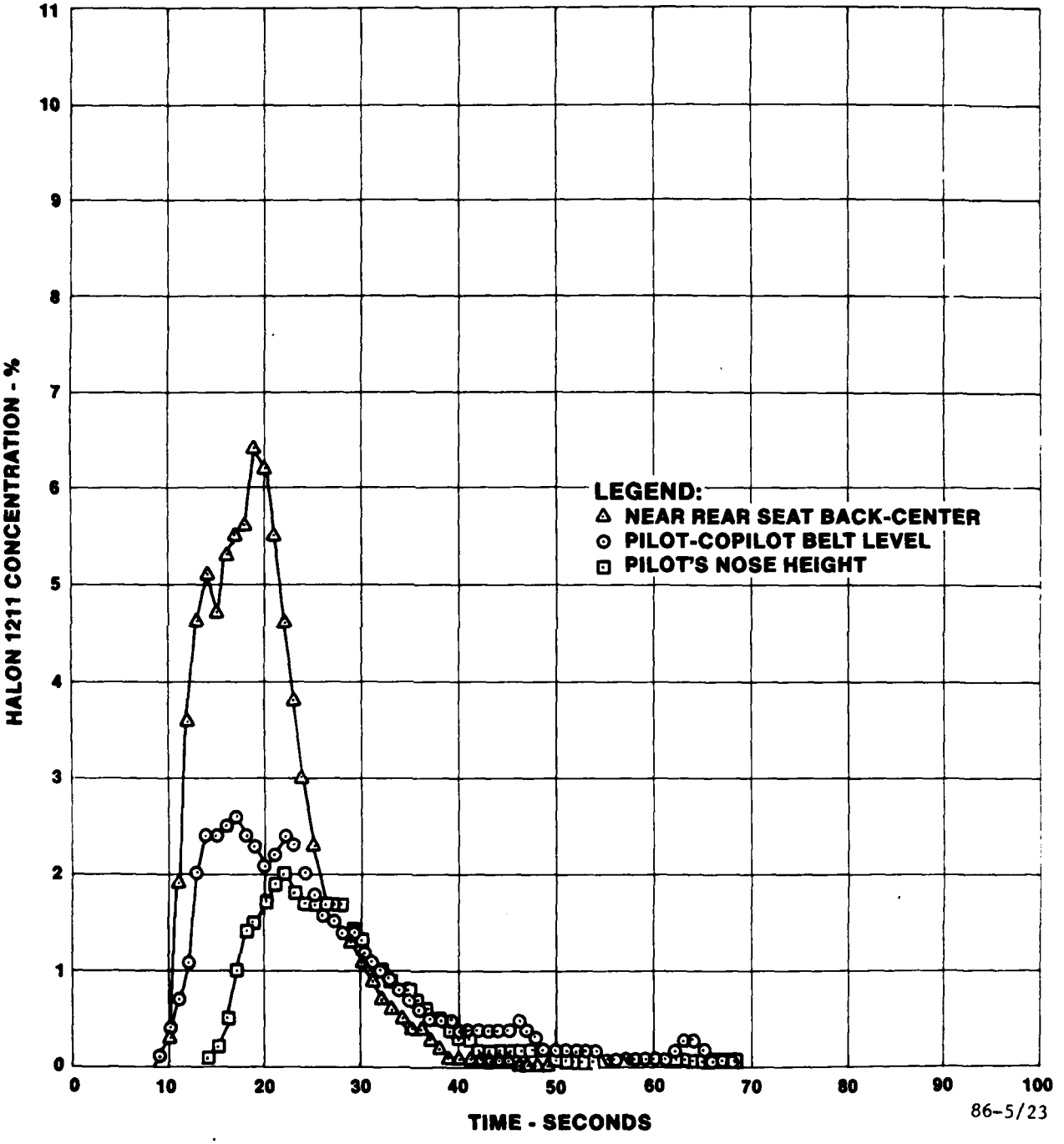


FIGURE 23. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE REAR SEAT - OVERHEAD VENTS OPEN

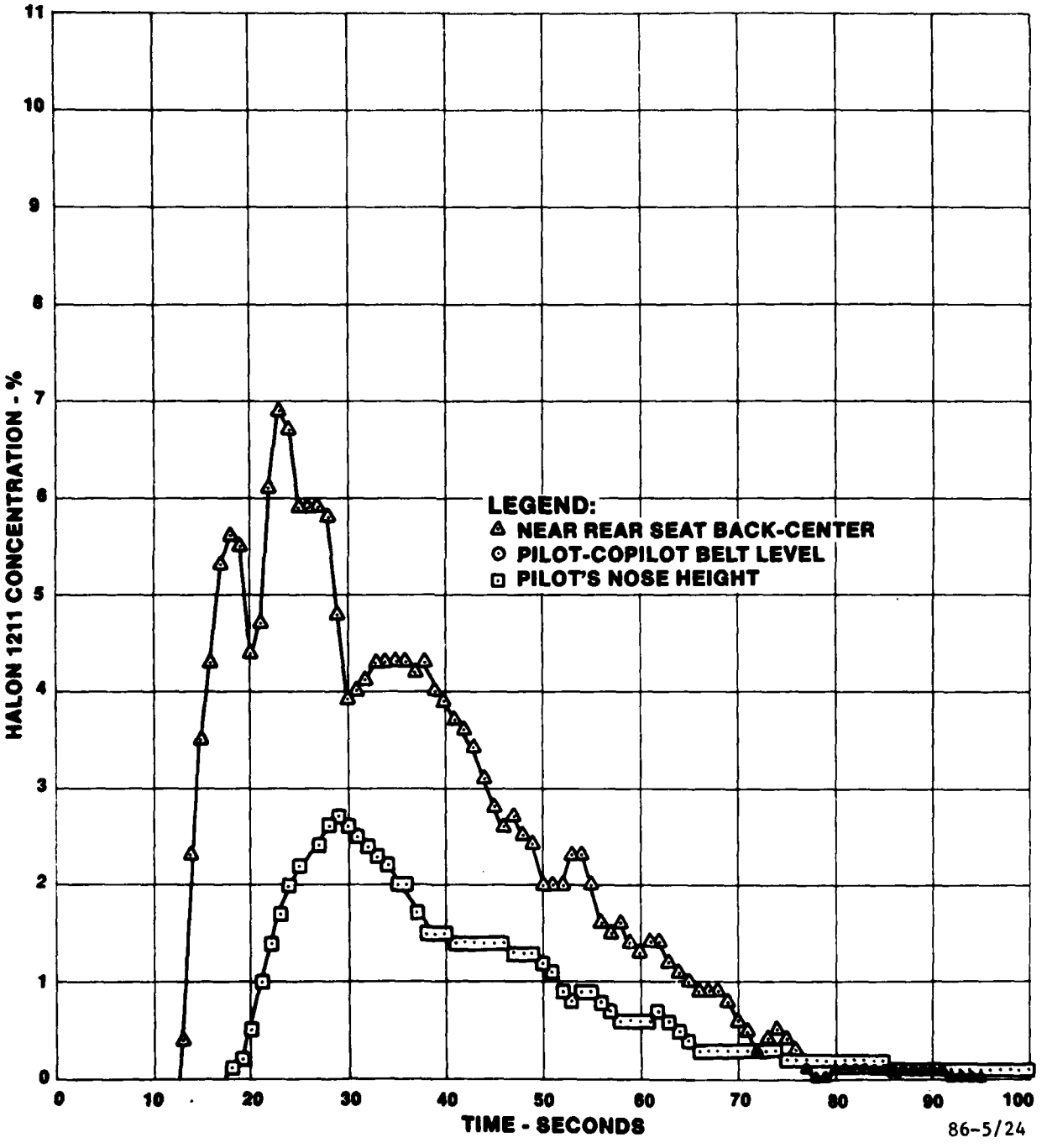


FIGURE 24. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE REAR SEAT - OVERHEAD VENTS CLOSED

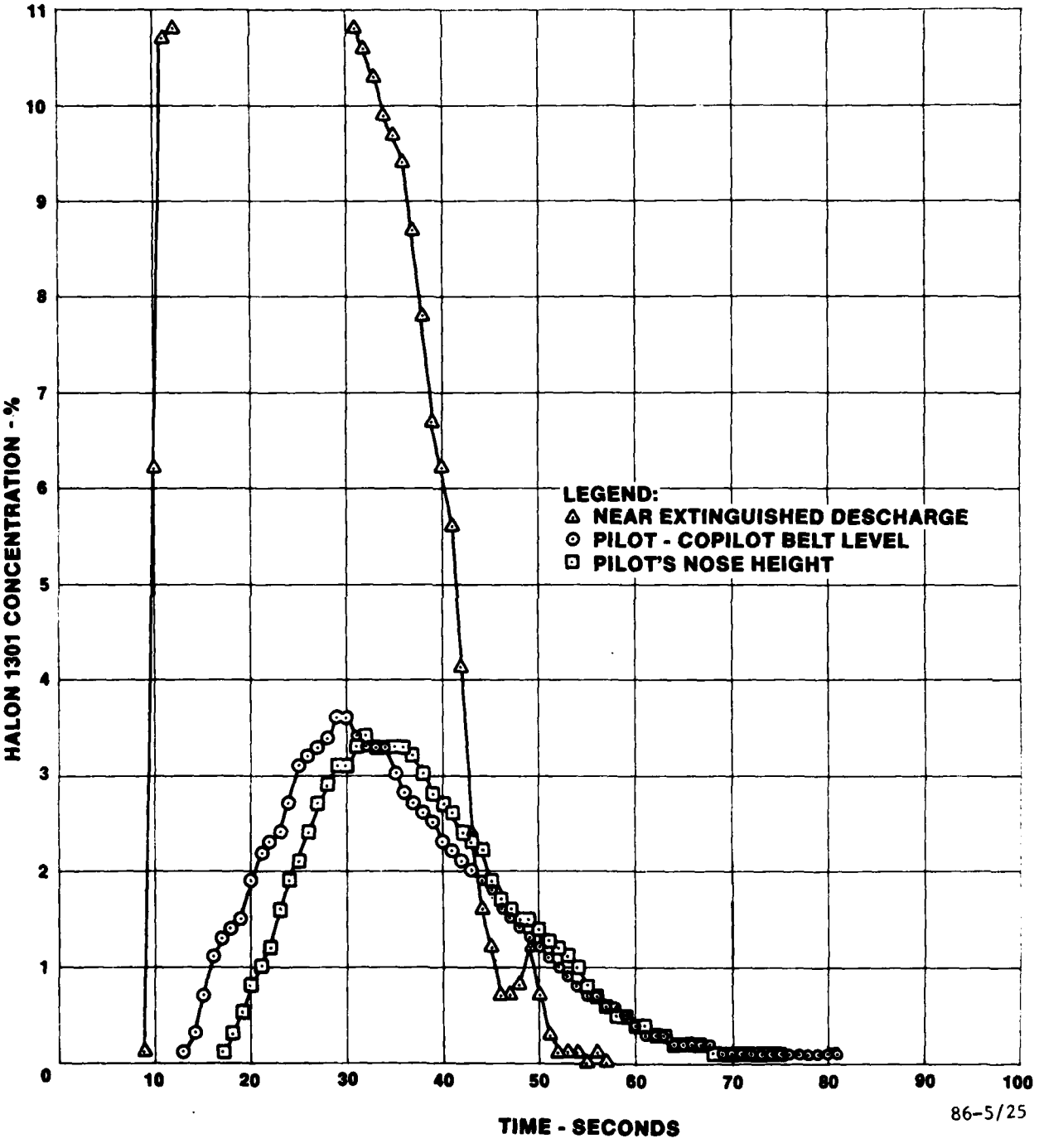


FIGURE 25. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE BAGGAGE CONPARTMENT - OVERHEAD VENTS OPEN

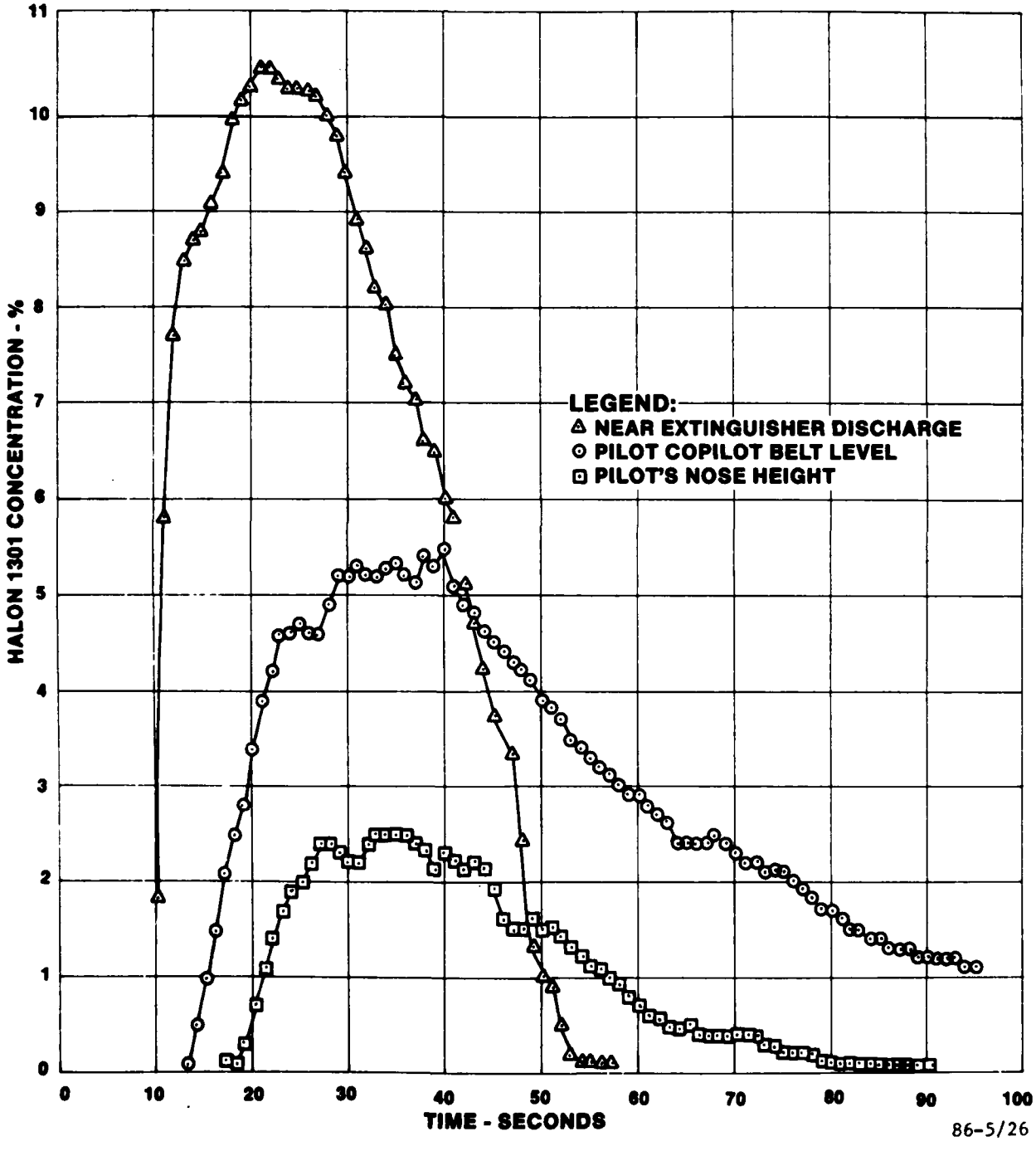


FIGURE 26. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE BAGGAGE COMPARTMENT - OVERHEAD VENTS CLOSED

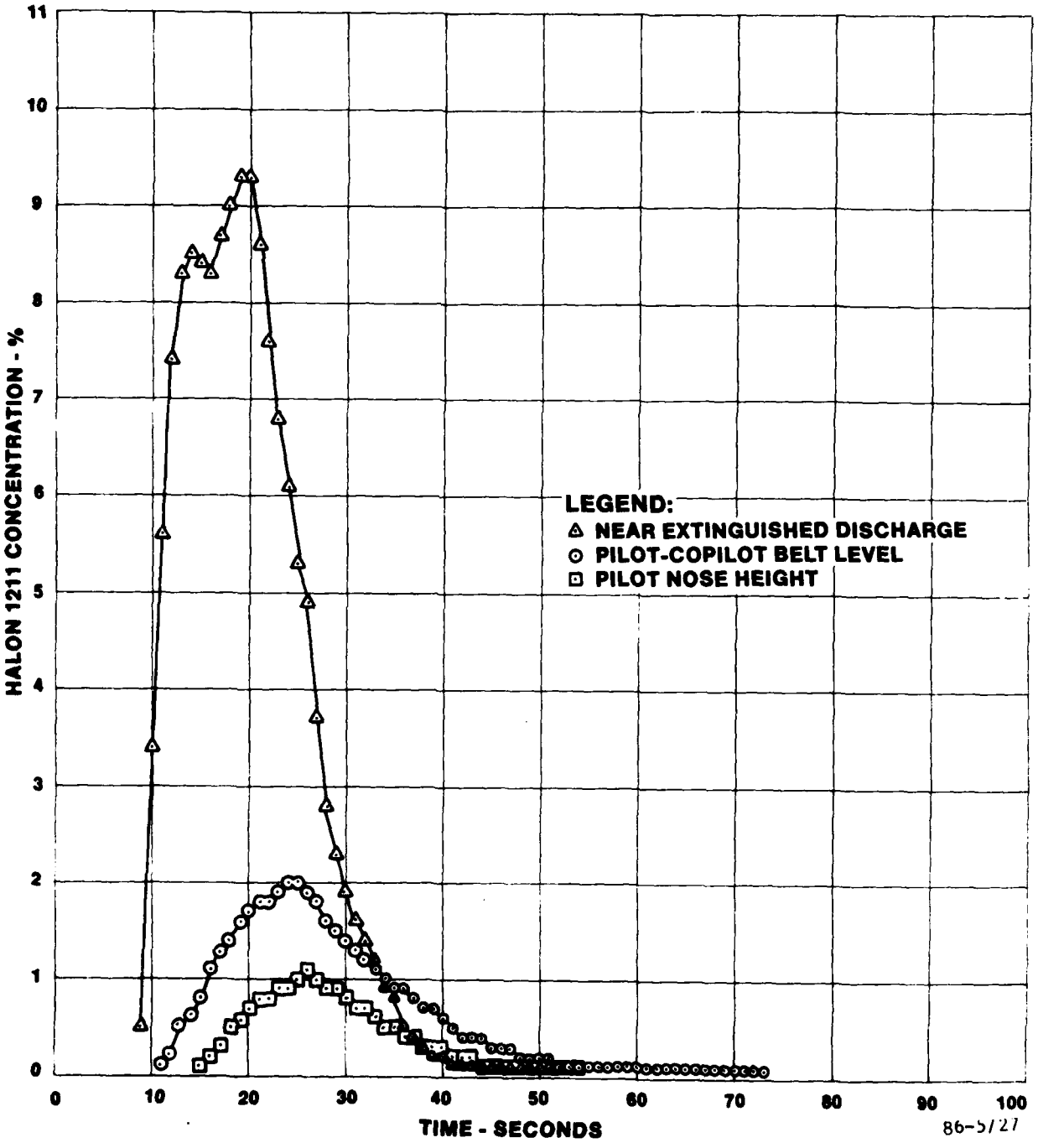


FIGURE 27. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE BAGGAGE COMPARTMENT - OVERHEAD VENTS OPEN

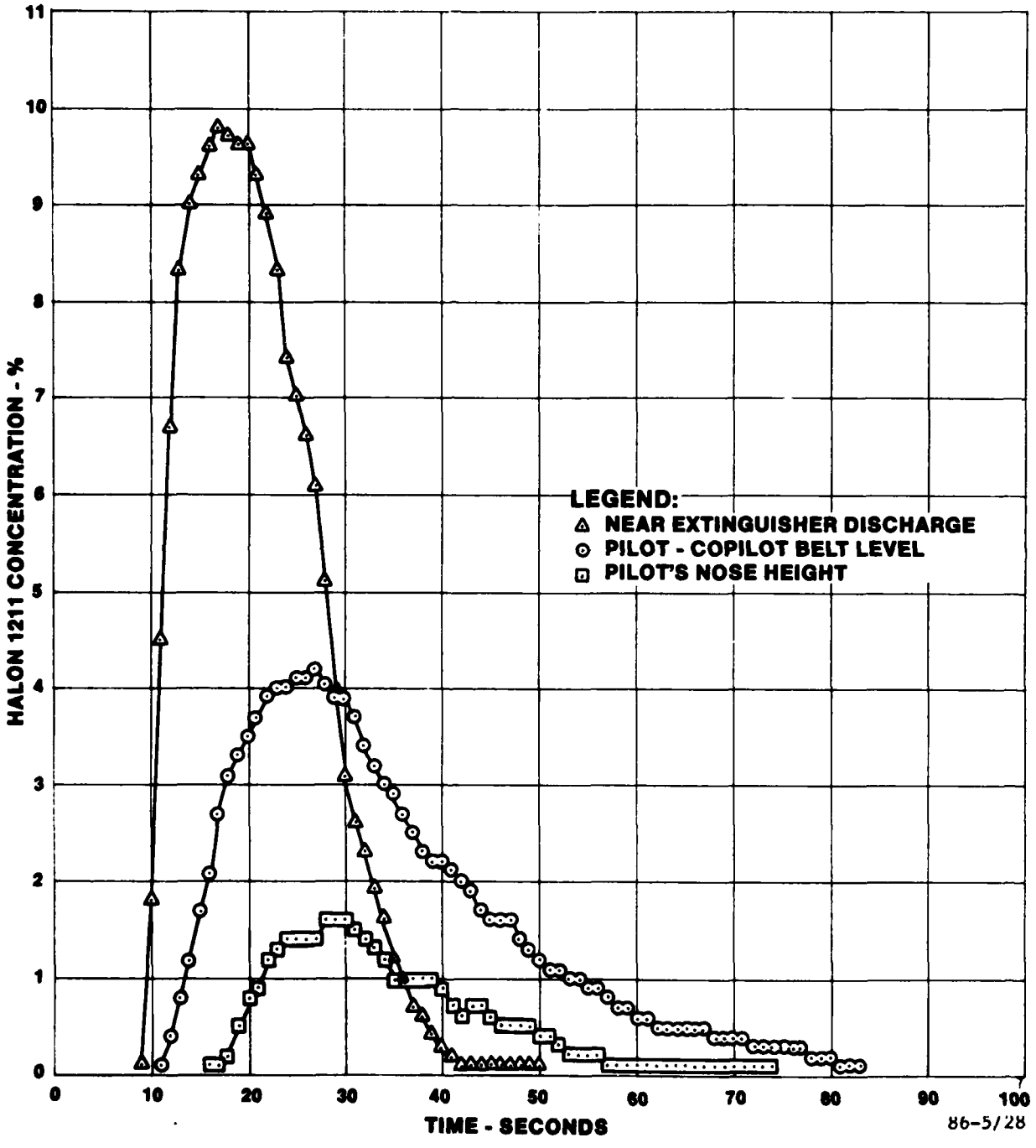


FIGURE 28. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE BAGGAGE COMPARTMENT - OVERHEAD VENTS CLOSED

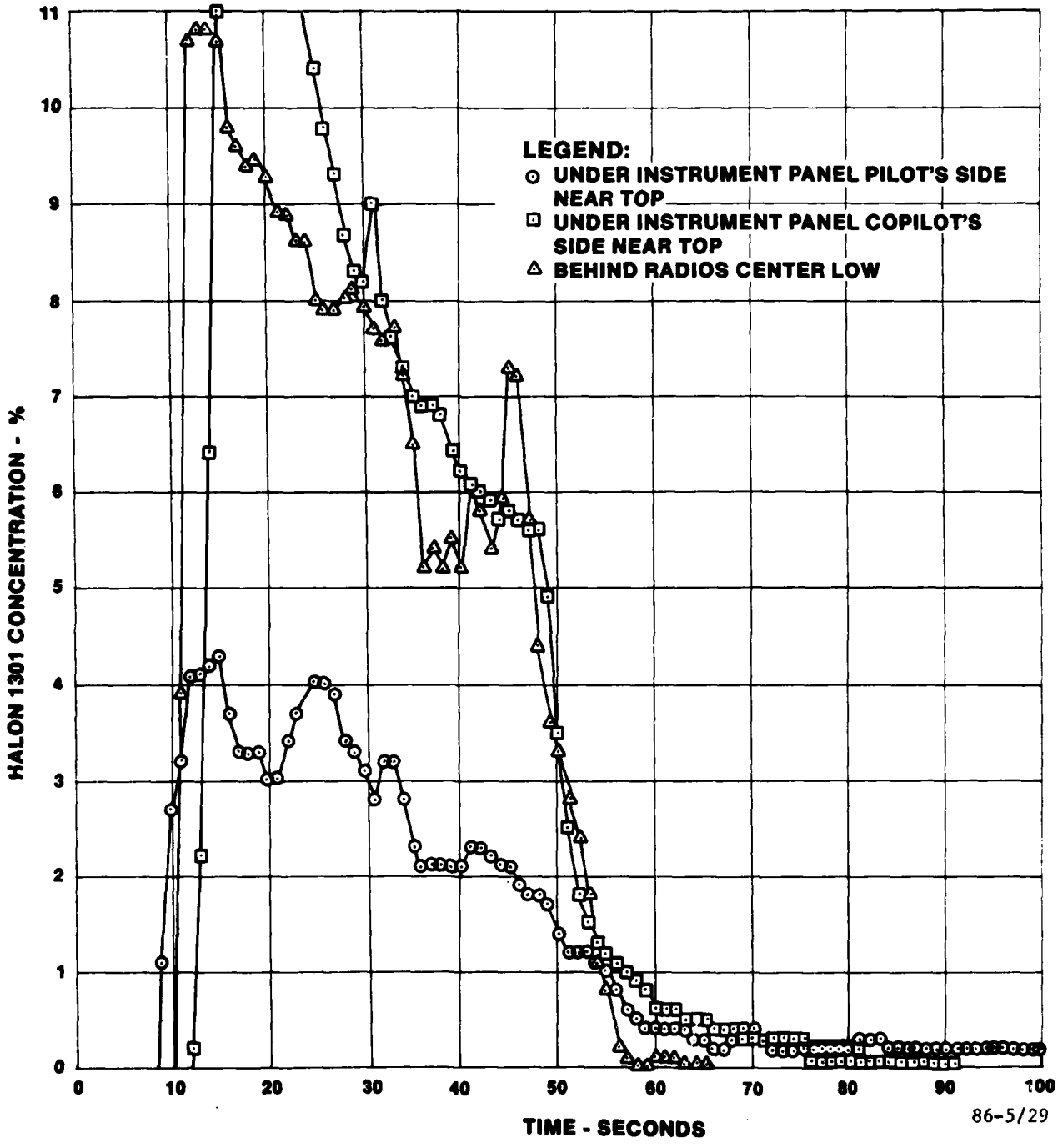


FIGURE 29. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED UNDER THE INSTRUMENT PANEL - COPILOT'S SIDE - ALL SAMPLE LINES UNDER INSTRUMENT PANEL

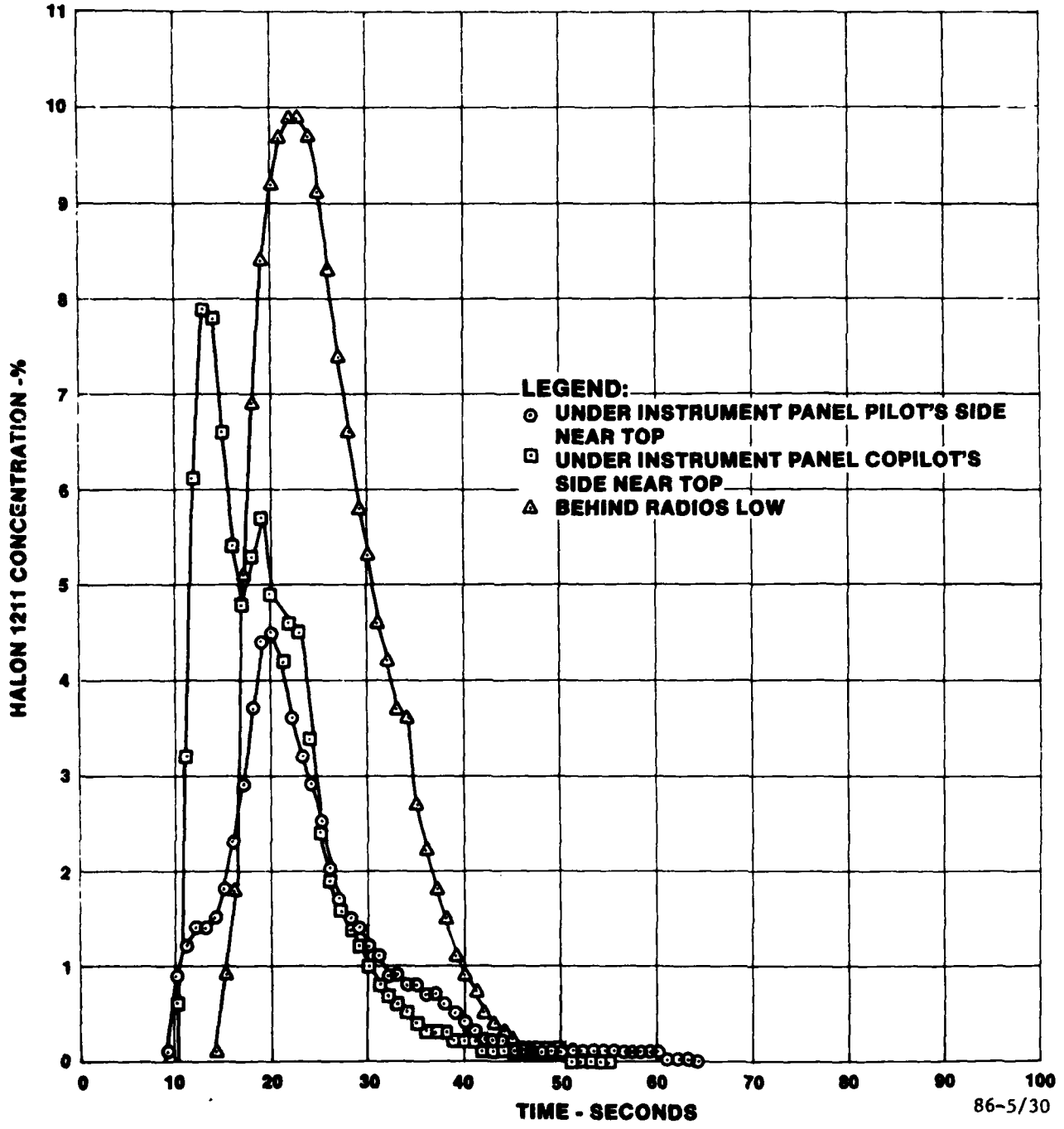


FIGURE 30. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED UNDER THE INSTRUMENT PANEL - COPILOT'S SIDE - ALL SAMPLE LINES UNDER INSTRUMENT PANEL

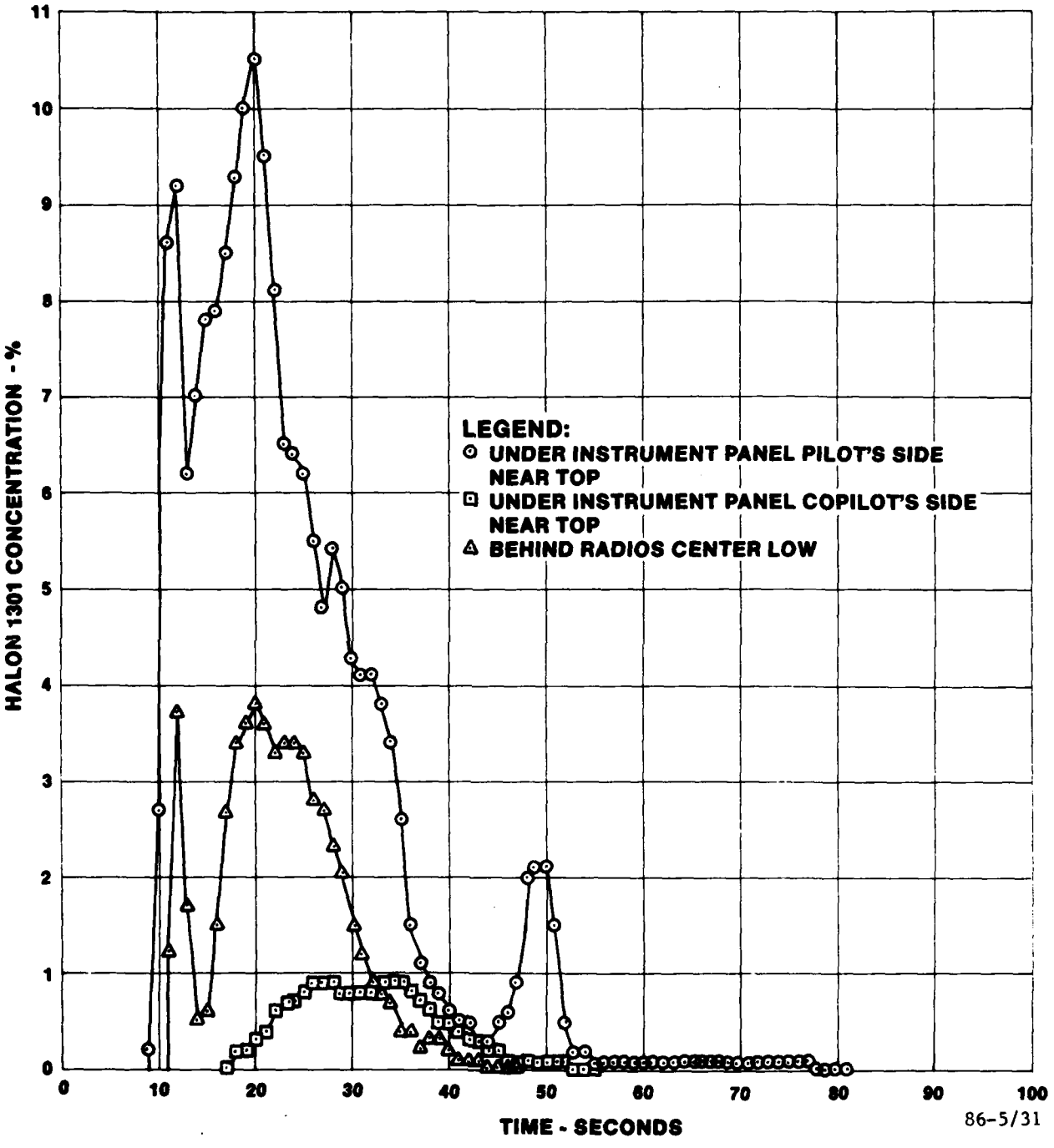


FIGURE 31. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED UNDER THE INSTRUMENT PANEL - PILOT'S SIDE - ALL SAMPLE LINES UNDER THE INSTRUMENT PANEL

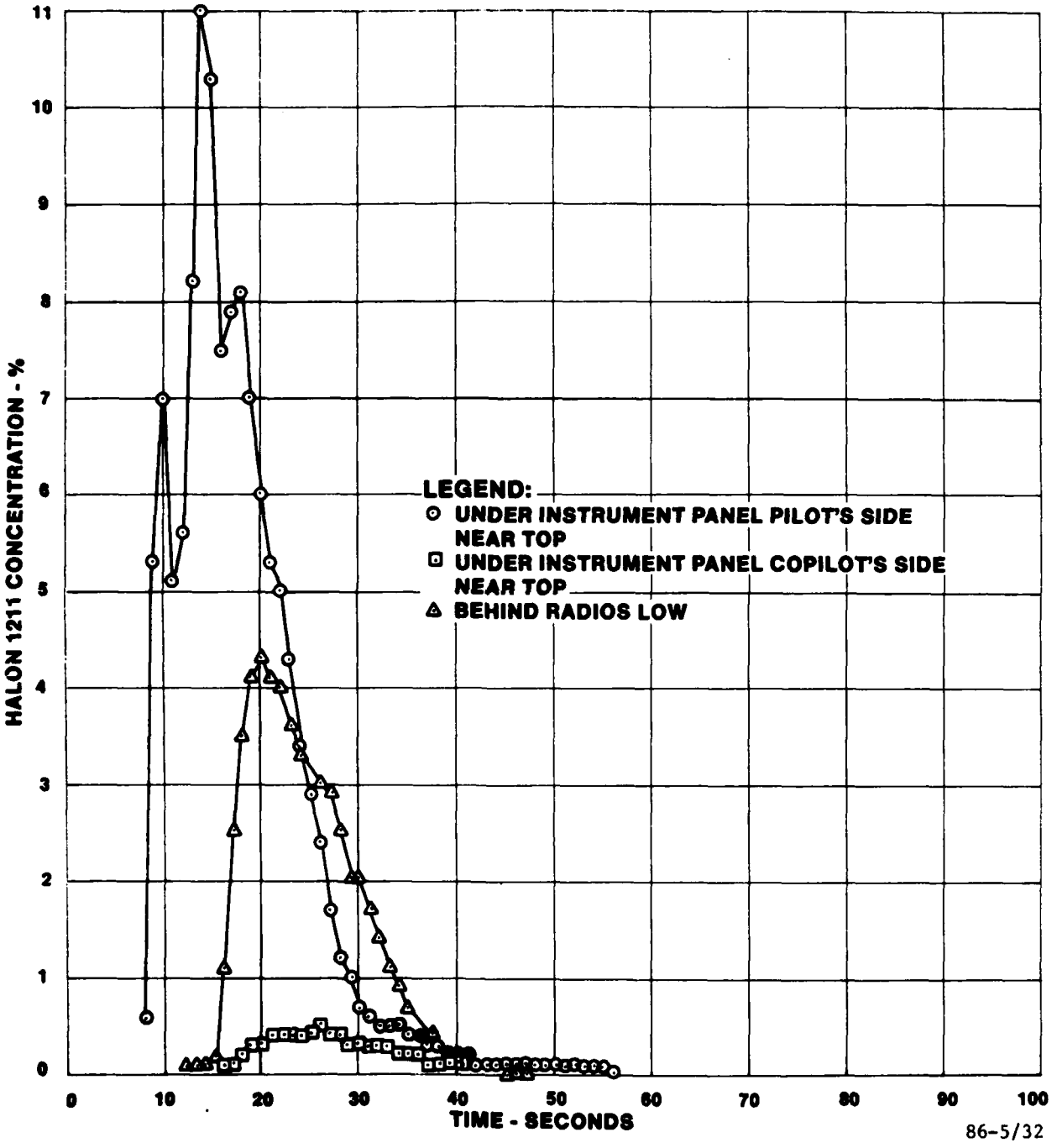


FIGURE 32. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED UNDER THE INSTRUMENT PANEL - PILOT'S SIDE - ALL SAMPLE LINES UNDER THE INSTRUMENT PANEL

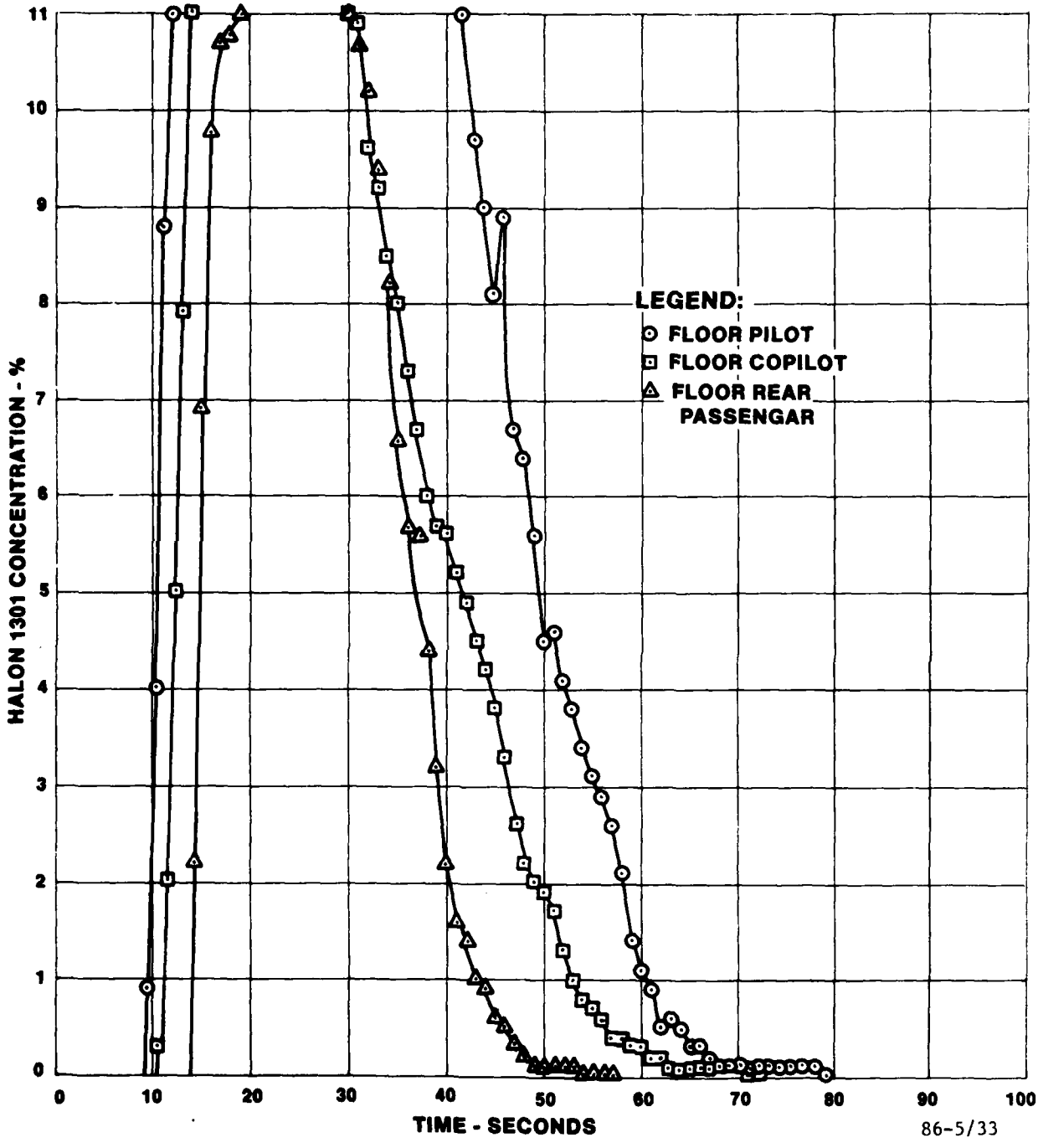


FIGURE 33. HALON 1301 CONCENTRATIONS - 3-POUND EXTINGUISHER DIRECTED TO THE FUEL AND HYDRAULIC SELECTOR VALVES - ALL SAMPLE LINES LOCATED ON THE FLOOR

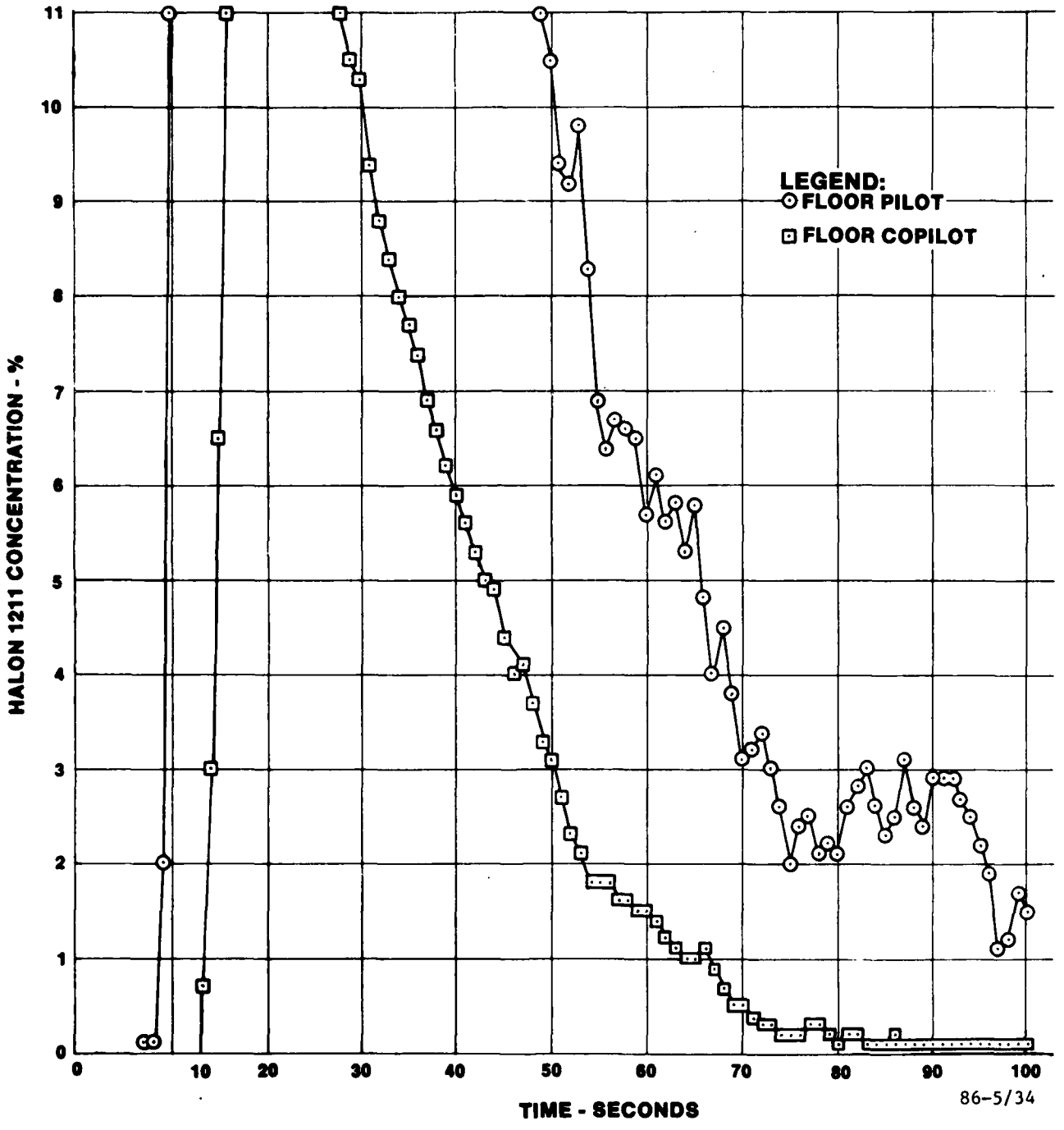


FIGURE 34. HALON 1211 CONCENTRATIONS - 2.5-POUND EXTINGUISHER DIRECTED TO THE FUEL AND HYDRAULIC SELECTOR VALVES - ALL SAMPLE LINES LOCATED ON THE FLOOR

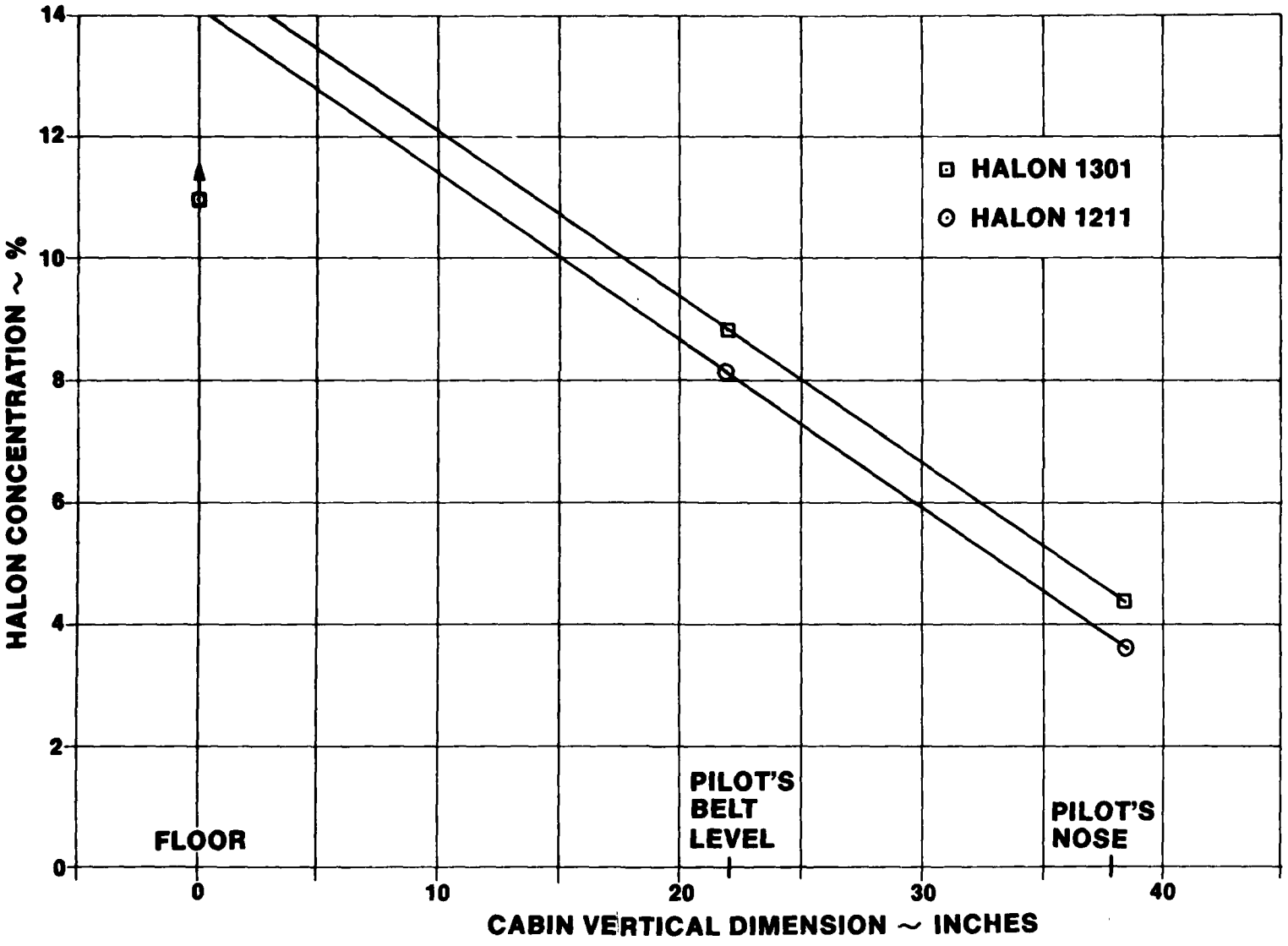


FIGURE 35. STRATIFICATION OF HALON EXTINGUISHING AGENTS

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